EXHIBIT A

THIS EXHIBIT HAS BEEN REDACTED IN ITS ENTIRETY

EXHIBIT B

THIS EXHIBIT HAS BEEN REDACTED IN ITS ENTIRETY

EXHIBIT C

United States Patent [19]

Nakahara et al.

[11] Patent Number: 4,714,253
[45] Date of Patent: Dec. 22, 1987

[54] **THREE-PIECE SOLID GOLF BALL**

[75] Inventors: **Akihiro Nakahara**, Ibaraki; **Taketo Matsuki**, Nishinomiya, both of Japan

[73] Assignee: **Sumitomo Rubber Industries, Ltd.**, Hyogo, Japan

[21] Appl. No.: **774,452**

[22] Filed: **Sep. 10, 1985**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 602,165, Apr. 19, 1984, abandoned.

[30] **Foreign Application Priority Data**

Apr. 21, 1983 [JP] Japan 58-70811

[51] **Int. Cl.**[4] **A63B 37/06**
[52] **U.S. Cl.** **273/228**; 273/230
[58] **Field of Search** 273/218, 220, 230, 219, 273/225, 228, 229

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,438,933 4/1969 Bartsch .... 273/218 X
3,553,159 1/1971 Miller et al. .... 273/218 X
4,141,559 2/1979 Melvin et al. 273/220
4,650,193 3/1987 Molitor et al. 273/228

FOREIGN PATENT DOCUMENTS

1095615 12/1967 United Kingdom 273/220

Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

[57] **ABSTRACT**

The present invention provides a three-piece golf ball having an excellent rebound coefficient without any damage to the durability of the golf ball by controlling the diameters, the specific gravities and the hardnesses of central core and outer layer of the solid core.

The golf ball of the present invention is a three-piece solid golf ball produced by covering a two-piece solid core made of a resilient elastomeric material, composed of a central core and an outer layer, with a cover made of an impact and wear resistant material, in which:

(1) the central core has a diameter of 20 to 32 mm and a specific gravity of 1.03 to 1.25, and the hardness (Shore C) of the central core is within the range of 57 to 80 at its center and is larger than that of its center but not more than 83 at a distance between 5 mm and 10 mm from its center, and

(2) the outer layer has a diameter of 36 to 40 mm, a specified gravity of 1.30 to 2.50 and a hardness (Shore C) of 70 to 83.

6 Claims, 1 Drawing Figure

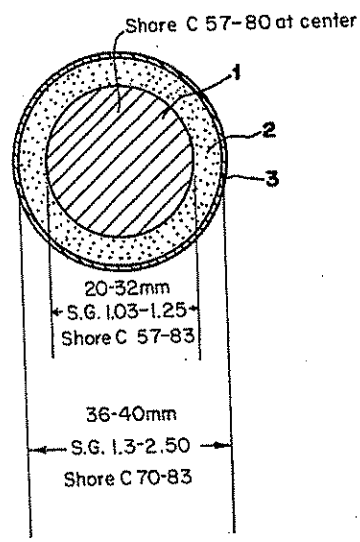
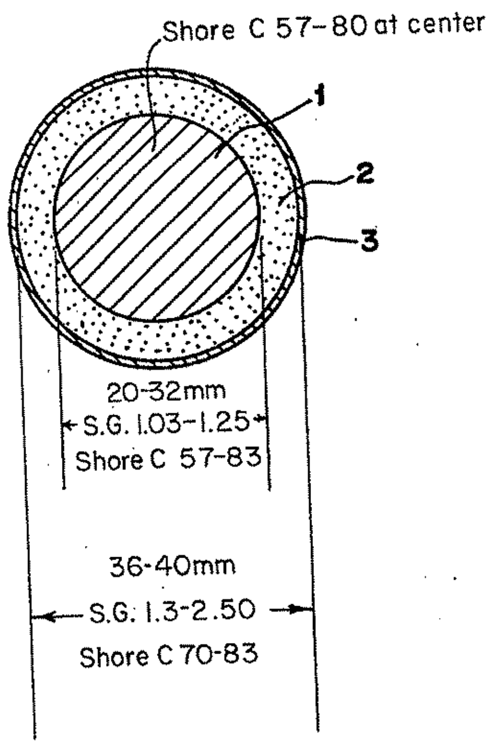


FIG. 1


Shore C 57-80 at center
1
2
3
20-32mm
S.G. 1.03-1.25
Shore C 57-83
36-40mm
S.G. 1.3-2.50
Shore C 70-83

THREE-PIECE SOLID GOLF BALL

RELATED APPLICATION

This application is a continuation-in-part of co-pending application, Ser. No. 602,165 filed on Apr. 19, 1984, now abandoned.

FIELD OF THE INVENTION

The present invention relates to a three-piece solid golf ball.

BACKGROUND OF THE INVENTION

A two-piece solid golf ball developed to improve the durability of thread wound golf balls, that is, a solid golf ball produced by covering an integrally molded solid core with a cover having excellent cutting resistance (for example, a cover made mainly of an ionomer resin produced by combining metallic ions to ethylene copolymers), has been found to possess an unsatisfactory rebound characteristic. The rebound characteristic largely affects the initial velocity of the ball and is an important property for governing the flight distance of the ball. Accordingly its improvement is necessary.

For a further improvement in the rebound characteristic of the two-piece solid golf ball, methods of improving the rebound characteristic of the solid core or increasing the moment of inertia of the ball, and the like have been considered. Since, however, the rebound characteristic of the solid core is substantially determined by the co-crosslinking, it is very difficult to improve the rebound characteristic. Also, in order to increase the moment of inertia of the ball, trials are being made to change the hardness distribution and weight distribution in the inside of the ball, but satisfactory results have not been obtained because defects, such as a reduction in durability, tend to appear.

SUMMARY OF THE INVENTION

The present invention provides a three-piece golf ball having an excellent rebound coefficient without adversely affecting the durability of the golf ball by controlling the diameters, the specific gravities and the hardnesses of the central core and outer layer of the two-piece solid core.

DETAILED DESCRIPTION OF THE INVENTION

Thus, the present invention provides a three-piece solid gold ball produced by covering a two-piece solid core made of a resilient elastomeric material, composed of a central core and an outer layer, with a cover made of an impact and wear resistant material, in which:

(1) the central core has a diameter of 20 to 32 mm and a specific gravity of 1.03 to 1.25, and the hardness (Shore C) of said central core is within the range of 57 to 80 at its center and is larger than that of its center but not more than 83 at the site between 5 mm and 10 mm apart from its center, and

(2) the outer layer has a diameter of 36 to 40 mm, a specified gravity of 1.30 to 2.50 and a hardness (Shore C) of 70 to 83.

Generally, the compositions of the central core and outer layer constituting the solid core of the three-piece solid golf ball according to the present invention are made of the same resilient elastomeric material, but if

desired, they may properly be changed within the scope of the present invention.

The component of the solid core includes, for example, substrate rubbers, crosslinking agents, co-crosslinking agents, inactive fillers and the like.

As the substrate rubber, natural rubbers and/or synthetic rubbers conventionally used for solid golf balls may properly be used, but in the present invention, 1.4-polybutadiene rubbers having a cis-structure in a proportion of at least not less than 40% are particularly preferred. If desired, however, natural rubbers, polyisoprene rubbers, styrene/butadiene rubbers or the like may properly be blended with the polybutadiene rubber.

As the crosslinking agent, there are given for example organic peroxides (e.g. dicumyl peroxide, t-butyl peroxide), azo compounds (e.g. azobisisobutyronitrile) and the like. Dicumyl peroxide is particularly preferred.

The amount of the crosslinking agent blended is generally 0.5 to 3.0 parts by weight, preferably 1.0 to 2.5 parts by weight based on 100 parts by weight of the substrate rubber.

The co-crosslinking agent is not particularly limited, and as its examples, the metallic salt of unsaturated fatty acids, particularly the zinc or magnesium salt of unsaturated fatty acids having 3 to 8 carbon atoms (e.g. acrylic acid, methacrylic acid) is given. But, zinc acrylate (normal salt) is particularly preferred. The amount of this agent blended is 30 to 40 parts by weight based on 100 parts by weight of the substrate rubber.

As the inactive filler, there are given for example zinc oxide, barium sulfate, silica, calcium carbonate, zinc carbonate and the like, of which zinc oxide is popularly used. The amount of the filler blended is governed by the specific gravity of the central core and outer layer, the standardized weight of the ball, etc., being not particularly limited. Generally, however, the amount is 3 to 150 parts by weight based on 100 parts by weight of the substrate rubber.

A composition for the central core obtained by blending the components described above is kneaded on the common kneaders such as banbury mixer, rolls, etc., and forced into a mold for the central core by compression or injection molding. The molded product is then heat-cured at a sufficient temperature for the crosslinking and co-crosslinking agents to act (for example, at about 150° C. to about 170° C. when the crosslinking agent is dicumyl peroxide and the other agent is zinc acrylate) to prepare the central core having a diameter of 20 to 32 mm and a specific gravity of 1.03 to 1.25.

In this case, it is important to properly regulate a heat-curing condition (for example, temperature-increasing rate, heating temperature, heating time) so that the central core has such a hardness (Shore C) distribution that the hardness of its center is 57 to 80 and that of a range between 5 mm and 10 mm apart from the center is larger than that of the center but not more than 83. Generally, Shore C hardness is measured by pricking a flat surface of a rubber material with a needle of a Shore C harness meter. Thus, the measurement of the central core is carried out by cutting the central core to form a hemisphere and measuring the hardness of the flat surface thereof.

When the specific gravity of the central core is made less than 1.03 it is almost impossible in terms of blending, while when said specific gravity is more than 1.25, the specific gravity of the outer layer approaches or becomes less than that of the central core, because of

which the effect of the present invention cannot be obtained.

Unless, the hardness distribution of the central core satisfies the foregoing condition, the expected object of the present invention cannot be attained.

The solid core of the golf ball according to the present invention is formed by applying an outer layer onto the central core prepared as above.

A composition for the outer layer obtained by blending and kneading the foregoing components is forced into a mold by compression or injection molding, when it is applied concentrically onto the central core in the mold. This two-layer molded product is then heat-cured at a sufficient temperature for the crosslinking and co-crosslinking agents blended in the outer layer to act to obtain a two-piece solid core of 36 to 40 mm in diameter.

Generally, the specific gravity of the outer layer is made 1.30 to 2.50, and the hardness (Shore C) thereof is made 70 to 83, preferably 72 to 75.

The two-piece solid core obtained as above is then covered with a cover, made of an impact and wear resistant material, of 1.4 to 2.7 mm in thickness. As the cover, those which are made mainly of an ionomer resin and if necessary, contains an inorganic filler (e.g. titanium dioxide, zinc sulfate) for the purpose of coloration, etc., are commonly used.

Preferred ionomer resins are thermoplastic resins obtained by giving a cross metallic bond to polymers of monoolefins with at least one member selected from the group consisting of unsaturated mono- or di-carboxylic acids having 3 to 8 carbon atoms and esters thereof (said polymer contains 4 to 30 wt.% of the unsaturated mono- or di-carboxylic acid and/or the ester thereof). As the type of ionomer resin, there are given, for example, various kinds of "Surlyn" resins marketed by Du Pont Co. (e.g. Surlyn 1601, 1707, 1605, etc. or their combination).

A method for covering the solid core with the cover is not particularly limited. Generally, the solid core is wrapped with two pieces of a cover molded in semi-spherical shell form, and then subjected to heat-pressure molding. But, the solid core may be wrapped by injection-molding the cover composition around it.

The three-piece solid golf ball of the present invention is a solid golf ball retaining durability equal to that of the conventional two-piece solid golf ball as well as having an improved rebound characteristic as compared with the prior art. In addition, the three-piece solid golf ball of the present invention is good in shot feeling, because the shock load at time of hitting is reduced and closely resembles the conventional balata wound golf ball.

The present invention will now be illustrated with reference to the following examples.

EXAMPLE 1

A composition for central core prepared according to the recipe in Table 1 was kneaded on a kneading roll and then pressure-molded at 160° C. for 20 minutes to prepare a solid central core of 28.0 mm in diameter.

A composition for outer layer, as blended according to the recipe in Table 1 and kneaded, was concentrically applied onto the central core by injection molding. This two-layer molded product was heat-treated at 165° C. for 25 minutes to obtain a two-piece solid core.

The obtained two-piece solid core was wrapped with two pieces of a cover in semi-spherical shell form (about 2 mm in thickness) prepared according to the recipe in Table 1, and pressure-molded at 155° C. for 15 minutes to obtain a three-piece solid golf ball of 41.3 mm in diameter.

The physical property of the produced ball is shown in Table 1.

TABLE 1

			Example 1	Example 2	Comparative example 1	Comparative example 2	Comparative example 3
Solid core	Composition of central core (part by weight)	Cis 1,4-polybutadiene (1)	100	100	100	100	100
		Zinc acrylate	36	36	36	36	36
		Zinc methacrylate	3.4	3.4	3.4	3.4	3.4
		Zinc oxide	4.5	32.8	50.1	63.6	96.8
		Dicumyl peroxide	1.0	1.0	1.0	1.0	1.0
		Antioxidant	1.0	1.2	1.2	1.3	1.4
	Composition of Outer layer (part by weight)	Cis 1,4-polybutadiene	100	100		100	100
		Zinc acrylate	36	36		36	36
		Zinc methacrylate	3.4	3.4		3.4	3.4
		Zinc oxide	83.0	59.1		36.2	15.0
		Dicumyl peroxide	1.0	1.0		1.0	1.0
		Antioxidant	1.4	1.3		1.2	1.0
Cover	Composition (part by weight)	Ionomer resin (2)	100	100	100	100	100
		Titanium dioxide	3	3	3	3	3
	Thickness (mm)		2.15	2.15	2.15	2.15	2.15
	Hardness (shore D)		68	68	68	68	68
Physical property	Hardness distribution (3)	Central core: Center	59.5	73.5	71.8	76.0	78.0
		Central core: Site 5 mm apart from the center	69.8	77.7	75.3	79.5	79.5
		Central core: Site 10 mm apart from the center	76.6	78.4	79.4	80.0	81.0
		Outer layer	80.4	80.3		79.0	78.0
	Diameter (mm)	Central core	28.0	28.0	37.0	28.0	28.0
		Outer layer	37.0	37.0	—	37.0	37.0
	Specific gravity	Central core	1.084	1.247	1.340	1.411	1.574
		Outer layer	1.508	1.388	—	1.266	1.146
	Weight (g)		35.5	35.6	35.6	35.7	35.7
	Compression (5)		48.8	48.7	48.8	48.9	48.8
	Rebound coefficient		+0.013	+0.006	±0.000	−0.007	−0.022
Physical property of ball	Flight distance (m)	Driver shot (head speed: 45.2 m/s) Carry	205.0	202.5	201.0	200.0	198.0
		Driver shot (head speed: 45.2 m/s) Total	236.7	234.1	232.3	231.5	229.0
		#5 Iron shot (head speed: 37.2 m/s) Carry	170.2	168.5	167.9	167.0	166.1
		#5 Iron shot (head speed: 37.2 m/s) Total	184.0	183.0	182.2	181.8	181.5
	rebound coefficient		+0.020	+0.006	±0.000	−0.007	−0.021

TABLE 1-continued

	Example		Comparative example		
	1	2	1	2	3
Durability index (4)	100	100	100	100	100
Shock load (6)	92	97	100	104	108

(1) JSR BR01
(2) A mixture of Surlyn 1601 and Surlyn 1707
(3) Shore C hardness
(4) A measurement value obtained by continuous hammering, as expressed in index with the value on the two-piece solid golf ball as 100.
(5) The deformation of the solid core in mil (mil = 1/1,000 inch). The deformation is measured by initially applying a 3.8 Kg weight to the solid core of the golf ball and then shifting the weight to 43.8 Kg.
(6) An index of shock load in terms of the two-piece golf ball of comparative example 1 of which value of shock load is made 100, measured by shooting a golf ball to be measured at 45 m/s with a golf club equipped with an acceleration meter. The smaller index is the smaller shock load, that is, the more soft. A wound golf ball covered by balata has the index of 90.

EXAMPLE 2

A three-piece golf ball was prepared as generally described in Example 1 by using the charge shown as Example 2 in Table 1.

The physical property of a three-piece solid golf ball is shown in Table 1.

Comparative Example 1

The physical property of a two-piece solid golf ball, as prepared according to the procedure of Example 1 except that the solid core is of a mono-layer structure, is shown in Table 1.

Comparative Examples 2 and 3

Three-piece golf balls were prepared according to the procedure of Example 1 by using the charges shown as Comparative Examples 2 and 3 in Table 1.

The physical property of three-piece solid golf balls is shown in Table 1.

As in shown in Table 1, by adjusting the specific gravity and hardness within the claimed range, the obtained golf ball has an improved rebound coefficient as well as a decreased shock load when it is hit by a club, in comparison with a conventional two-piece golf ball. The conventional two-piece golf ball had a bad feeling at hitting, because the shock load is strong. By the present invention, the shot feeling is approached to a wound golf ball covered by balata.

What is claimed is:

1. A three-piece solid golf ball having high durability and improved rebound characteristics which comprises a two-piece solid center made of a resilient elastomeric material having a central core and an outer layer, and a cover made of an impact and wear resistant material, wherein

(1) the central core has a diameter of 20 to 32 mm and a specific gravity of 1.03 to 1.25, with the center point of the central core having a hardness (Shore C) within the range of 57 to 80 with the center core, at a distance between 5 mm and 10 mm from its center point, having a shore hardness higher than that at the center point but not more than 83, and

(2) the outer layer has an outer diameter of 36 to 40 mm, a specified gravity of 1.30 to 2.50 and a hardness (Shore C) of 70 to 83.

2. The three-piece solid golf ball of claim 1 wherein the cover has a thickness of 1.4 to 2.7 mm.

3. The three-piece solid golf ball of claim 1 wherein the cover is made of an ionomer resin.

4. The three-piece solid golf ball of claim 1 wherein the resilient elastomeric material is 1,4-polybutadiene rubber having at least 40% of a cis-structure.

5. The three-piece solid golf ball of claim 3 wherein the ionomer resins are thermoplastic resins obtained by crosslinking polyolefins with a metallic bond and with at least one member selected from the group consisting of unsaturated mono- or di-carboxylic acids having 3 to 8 carbon atoms and ester thereof.

6. The three-piece solid golf ball of claim 4 wherein the polybutadiene rubber is blended with natural rubbers, polyisoprene rubbers, and styrene-butadiene rubbers.

* * * * *

EXHIBIT D

United States Patent [19]

Nakahara et al.

[11] **Patent Number: 5,002,281**

[45] **Date of Patent: Mar. 26, 1991**

[54] **THREE-PIECE SOLID GOLF BALL**

[75] Inventors: **Akihiro Nakahara**, Ibaraki; **Mikio Yamada**, Kobe; **Tadahiro Ebisuno**, Nishinomiya; **Kengo Oka**, Kobe; **Takashi Sasaki**, Nishinomiya, all of Japan

[73] Assignee: **Sumitomo Rubber Industries, Ltd.**, Hyogo, Japan

[21] Appl. No.: **485,656**

[22] Filed: **Feb. 27, 1990**

[30] **Foreign Application Priority Data**

Mar. 1, 1989 [JP] Japan 1-49025

[51] **Int. Cl.**[5] **A63B 37/12**

[52] **U.S. Cl.** .... **273/220**; 273/218; 273/235 R; 273/230

[58] **Field of Search** .... 273/218, 220, 62, 230, 273/231, 235 R, 230, 228, 229

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,313,545	4/1967	Bartsch	273/218
3,784,209	1/1974	Berman et al.	273/218
4,570,937	2/1986	Yamada	273/218
4,625,964	12/1986	Yamada	273/220
4,919,434	4/1990	Saito	273/218

FOREIGN PATENT DOCUMENTS

62-181069	8/1987	Japan	273/218
63-61029	11/1988	Japan	273/218
2139101	11/1984	United Kingdom	273/220

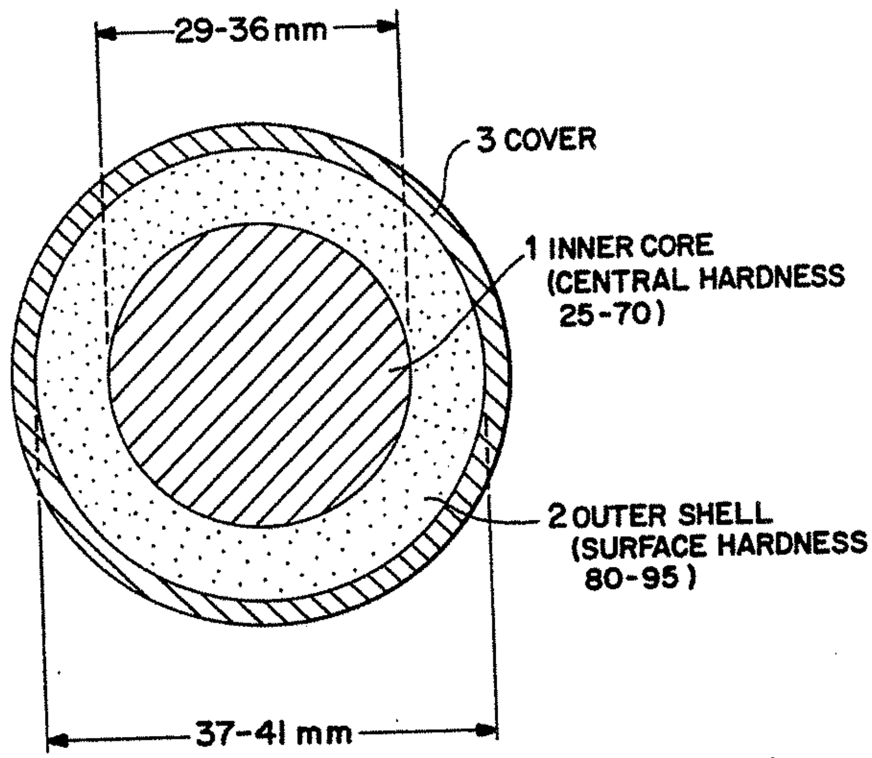
Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

[57] **ABSTRACT**

Disclosed is a three-piece solid golf ball comprising a solid core consisting of an inner core and an outer shell surrounding said inner core, and a cover covering said solid core, characterized in that a diameter of said inner core is 29 to 36 mm, a diameter of said solid core is 37 to 41 mm, a central hardness (JIS-C) of the inner core is 25 to 70, a surface hardness (JIS-C) of said outer shell is 80 to 95, a difference between said central hardness of the inner core and said surface hardness of the outer shell is 10 or more, and the relation between the specific gravity of the inner core and the specific gravity of the outer shell satisfies 1.0 $<$a specific gravity of the inner core $\leqq$a specific gravity of the outer shell $<$1.3.

3 Claims, 1 Drawing Sheet

FIGURE


29-36mm
3 COVER
1 INNER CORE
(CENTRAL HARDNESS
25-70)
2 OUTER SHELL
(SURFACE HARDNESS
80-95)
37-41 mm

THREE-PIECE SOLID GOLF BALL

FIELD OF THE INVENTION

The invention relates to a large-sized three-piece solid golf ball superior in impact resilience and flying distance.

BACKGROUND OF THE INVENTION

A large number of patent applications have been made for three-piece solid golf balls, but those, in particular, with a large size, superior to a two-piece golf ball in performance, that is impact resilience, flying distance and hit feeling which are important for golf balls, have not been developed yet.

For example, Japanese Patent Publication (examined) No. 61029/1988 proposes that a lower specific gravity is given to an inner layer (inner core) of a solid core and a higher specific gravity is given to an outer layer (outer shell) of the solid core to give a differential specific gravity, whereby obtaining high impact resilience and good hit feeling. For small size golf balls, the high impact resilience has been obtained because a sufficient specific gravity difference can be obtained, however, for large size golf balls satisfactory impact resilience, flying distance and hit feeling have not been obtained yet. In addition, according to Japanese Kokai Application No. (unexamined) 181069/1987, a diameter of a solid core is relatively reduced to an extent of 24 to 29 mm and a differential specific gravity is given between an inner layer having a higher specific gravity and an outer layer having a lower specific gravity to obtain increased flying distance, good hit feeling and controllability. However, impact resilience and flying distance have not exceeded those of the two-piece golf ball, which has been used at present. Furthermore, since TMPT (U.S. Pat. No. 3,313,545), which has been hardly used at present, is used in the inner layer, the three-piece golf balls according to Japanese Kokai Application 181069/1987 are remarkably inferior to the two-piece golf ball, which has been used at present, in durability.

Besides, according to Japanese Kokai Publication No. 241464/1985, a differential specific gravity is given between an inner layer having a larger specific gravity and an outer layer having a lower specific gravity in the same manner as in the above described Japanese Kokai Application No. 181069/1987 and the inner layer is made softer to reduce a moment of inertia of a ball, whereby obtaining the high impact resilience and the good hit feeling. This ball is satisfactory in hit feeling, but inferior to the two-piece golf ball in maximum impact resilience.

SUMMARY OF THE INVENTION

The present inventors have found from their investigation of three-piece solid golf balls that the conventionally proposed three-piece golf balls are all suitable for small-sized golf balls but not always suitable for large-size golf balls. That is to say, it is thought that the large-size golf ball required a construction peculiar thereto.

It is an object of the present invention to develop a large-size three-piece golf ball having impact resilience higher than that of the conventional two-piece golf ball and improved hit feeling, and flying capacity such as flying distance. The golf ball comprises a solid core consisting of an inner core and an outer shell surrounding the inner core, and a cover covering the solid core, characterized in that a diameter of the inner core is 29 to 36 mm, a diameter of the solid core is 37 to 41 mm, a central hardness (JIS-C) of the inner core is 25 to 70, a surface hardness (JIS-C) of the outer shell is 80 to 95, a difference between the central hardness of the inner core and the surface hardness of the outer shell is 10 or more, and the relation between the specific gravity of the inner core and the specific gravity of the outer shell satisfies 1.0 < a specific gravity of the inner core ≦ a specific gravity of the outer shell < 1.3.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

The FIGURE shows the three-piece solid golf ball of the present invention, wherein element **1** represents the inner core, element **2** represents the outer shell and element **3** represents the golf ball cover.

DETAILED DESCRIPTION OF THE INVENTION

In general, the inner core (**1**) and the outer shell (**2**) constituting the solid core of the three-piece solid golf ball may be suitably changed in rubber composition within the scope of the present invention if desired. The rubber composition of the solid core generally comprises a base rubber, a cross-linking agent, a cocross-linking agent, fillers and the like.

The base rubber can be natural rubber and/or synthetic rubber, but 1,4-polybutadiene containing a cis-structure in a quantity of at least 40% or more is in particular useful in the present invention. A natural rubber, a polyisoprene rubber, a styrene butadiene rubber and the like may be suitably added to the polybutadiene if necessary.

The cross-linking agent includes organic peroxides, such as dicumyl peroxide and t-butyl peroxide; azo compounds, such as azo-bis-isobutylnitrile; and the like. Dicumyl peroxide is in particular preferably used. The cross-linking agent is used in a quantity of 0.5 to 3.0 parts by weight, preferably 1.0 to 2.5 parts by weight, based on 100 parts by weight of the base rubber.

The cocross-linking agent is not specially limited, but metallic salts of unsaturated fatty acids, in particular a zinc salt and a magnesium salt of unsaturated fatty acids containing 3 to 8 carbon atoms (for example acrylic acid, methacrylic acid and the like), can be employed. Zinc acrylate (normal salt) is in particular preferably used. It is used in a quantity of 5 to 25 parts by weight for the inner core, 25 to 50 parts by weight for the outer shell, based on 100 parts by weight of the base rubber.

The fillers may be zinc oxide, barium sulfate, silica, calicium carbontae, zinc carbonate and the like, but zinc oxide is more general. They are used in a quantity depending upon the specific gravities of the inner core and outer shell, the weight standard of the ball and the like but not specially limited, generally 3 to 150 parts by weight based on 100 parts by weight of the base rubber.

A rubber composition for the inner core of the solid core can be obtained by mixing the above described ingredients in a usual blender, for example a Banbury mixer, a roll and the like. The resulting blend is compression molded or injection molded in a metal mold for the inner core followed by heating at a temperatures

sufficient for the action of the cross-linking agent and the cocross-linking agent (for example about 150° to 170° C. in the case where dicumyl peroxide is used as the cross-linking agent and zinc acrylate is used as the cocross-linking agent) to harden the molded product, whereby producting the inner core of the solid core having a diameter of 29 to 36 mm, preferably 30 to 34 mm, and a specific gravity of 1.0 to 1.3. If the diameter of the inner core is less than 29 mm, the shock when hit the ball is increased and the hit feeling is deteriorated while if it exceeds 36 mm, the thickness of the outer shell is reduced, whereby the hit feeling is too soft and also the durability is reduced.

In this case, it is important to suitably adjust the heating-hardening conditions (for example the temperature-rise rate, the heating temperature, the heating time and the like) so that the hardness (JIS-C) of the inner core of the solid core may amount to 25 or more but less than 70, preferably 40 to 65, at the center thereof. If the hardness at the center is less than 25, the hit feeling is too soft the impact resilience is deteriorated. If the hardness is more than 70, the ball is too hard and the hit feeling is bad, whereby the ball can not be practically used.

The solid core according to the present invention is produced by further forming the outer shell on the inner core obtained above.

That is to say, the rubber composition for the outer shell of the solid core is obtained by mixing and blending the above mentioned ingredients and concentrically compression molded on the inner core. The resulting two-layer molded product is heated to be hardened at the temperatures sufficient for the action of the cross-linking agent and the cocross-linking agent contained in the outer shell to obtain the solid core having a diameter of 37 to 41 mm. If the diameter of the solid core is 37 mm or less, the cover is too thick and thus the impact resilience is reduced, while if it is 41 mm or more, the cover is too thin and thus the durability is deteriorated.

The surface hardness (JIS-C) of the outer shell is set at 80 to 95, preferably 85 to 92. If the surface hardness of the outer shell is less than 80, the impact resilience is deteriorated, while if it exceeds 95, the impact resilience is improved but the durability is deteriorated.

According to the present invention, it is required that the difference between the hardness at the center of the inner core and the surface hardness of the outer shell is 10 or more. In other words, it is preferably that the inner core is considerably softer than the outer shell. According to the investigation by the present inventors, the shock when the ball is hit is reduced with a reduction of the hardness of the inner core and the impact resilience is improved with an increase of the hardness of the outer shell. If the above described difference is less than 10, the impact resilience is reduced and the shock when the ball is hit is increased.

According to the present invention, also the specific gravities of the inner core and the outer shell are important and it is required that the relation between both specific gravities satisfies the following expression (1):

$$1.0 < \text{specific gravity of the inner core} \leqq \text{specific gravity of the outer shell} < 1.3 \quad (1)$$

It has been found that, although the increased difference between the specific gravity of the inner core and that of the outer shell is preferable for the small-size ball, the impact resilience is hardly influenced by the distribution of specific gravity for the large-size ball. In respect of the shock when the ball is hit, it is rather preferable that the specific gravity shows no distribution (specific gravity of the inner core ≈ specific gravity of the outer shell). Accordingly, in view of the impact resilience and the shock when the ball is hit, it is necessary to meet the above described expression (1).

With the above described construction, the large-size three-piece golf ball with the reduced quantity of spin influencing upon the fly of the ball and the tendency to increase the hitting-up angle and thus showing the flying distance exceeding that of two-piece golf balls and the good feeling was obtained.

The two-piece solid core obtained in the above described manner is covered with a cover of 0.9 to 2.9 mm thick. The cover is generally formed from mainly ionomer resins and if necessary, inorganic fillers (for example titanium dioxide, zinc oxide and the like).

The preferable ionomer resins are thermoplastic resins obtained from polymers of monoolefines and at least one kind selected from the group consisting of unsaturated mono- or dicarboxylic acids containing 3 to 8 carbon atoms and esters thereof (containing unsaturated mono- or dicarboxylic acids, and/or esters thereof in a quantity of 4 to 30% by weight), which contains metallic cross bonds. The ionomer resins include various kinds of "Surlyn" (for example Surlyn 1601, 1707, 1605 and in combination) marked by DuPont de Nemours & Co., Ltd.

A method of covering the solid core with the cover is not specially limited. In usual, the solid core is covered with two pieces of cover, which have been previously molded in the shape of a semispherical shell, followed by heating and compression molding. However, the composition for the cover may be injection molded to cover the solid core.

The large-size three-piece solid golf ball obtained in the present invention exhibits impact resilience higher than that of the conventional two-piece golf ball, good hit feeling and improved flying capacities such as flying distance.

EXAMPLES

The present invention is below described with reference to the preferred examples but not limited by them. In addition, the positions, where the distribution of hardness is measured, are all specified with the center as a base. For example, 5 to 10 mm indicates the position at a distance of 5 to 10 mm from the center.

EXAMPLES 1 TO 5

The compositions for the inner core of the solid core shown in Table 1 were subjected to the pressure molding for 30 minutes at 155° C. to produce inner cores.

The compositions for the outer core of the solid core shown in Table 1 were concentrically pressure molded on the above described inner cores and then heated for 30 to 40 minutes at 155° C. to obtain two-piece solid cores.

The resulting two-piece solid cores were covered with the compositions for the covers shown in Table 1 by the injection molding to produce large-size three-piece solid golf balls.

The physical properties of the produced balls are shown in Table 1.

COMPARATIVE EXAMPLES 1 TO 7

Three-piece solid golf balls were obtained in the same manner as in Example 1 using the compositions shown in Table 1. The physical properties of the obtained golf balls are shown in Table 1.

Comparative Examples 1 to 3 and 7 relate to the golf balls having the diameter of the inner core of less than 29 mm, Comparative Examples 2, 6 and 7 relating to the golf balls in which the specific gravity of the inner core is larger than that of the outer core, comparative Example 4 relating to the golf ball in which the inner core has the hardness of less than 25 at the center thereof and the hardness of less than 40 at the distance of 5 to 10 mm form the center thereof, and Comparative Example 5 relating to the golf ball in which the inner core has the hardness of 70 or more at the center thereof and the hardness of 70 or more at the distance of 5 to 10 mm from the center thereof.

COMPARATIVE EXAMPLE 8

The first-class two-piece golf ball on the market was tested on physical properties. The results are shown in Table 1.

TABLE 1

	Examples No.					Comparative Examples No.							
	1	2	3	4	5	1	2	3	4	5	6	7	8
Solid core, Inner layer, Composition (parts by weight): Cis-1,4-polybutadiene[1]	100	100	100	100	100	100	100	100	100	100	100	100	*
Zinc acrylate	7	13	13	20	22	12	12	13	4	25	13	—	
TMPT	—	—	—	—	—	—	—	—	—	—	—	13	
Zinc oxide	29.5	27.3	21.0	24.9	24.2	27.7	57.0	27.3	30.5	23.1	51.6	64.8	
N,N-phenylene-maleimide	—	—	—	—	—	—	—	—	—	—	—	2	
Antiaging agent	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	
Dicumyl peroxide	1.5	1.5	1.6	1.5	1.5	1.5	1.4	1.5	1.0	1.5	1.5	1.2	
Diameter (mm)	31.0	31.0	31.0	31.0	34.2	24.2	24.2	27.1	31.0	31.0	31.0	24.2	
Specific gravity	1.151	1.151	1.110	1.151	1.151	1.151	1.332	1.151	1.151	1.151	1.301	1.332	
Central hardness (JIS-C)	30	50	51	60	62	45	44	50	20	71	50	45	
5 to 10 mm hardness (JIS-C)	45	60	62	68	70	48	46	61	38	75	57	46	
Solid core, Outer layer, Composition (parts by weight): Cis-1,4-polybutadiene	100	100	100	100	100	100	100	100	100	100	100	100	100
Zinc acrylate	45	45	40	47	48	40	40	45	45	45	28	40	
Zinc oxide	16.0	16.0	35.9	15.3	15.0	17.8	13.6	16.0	16.0	16.0	4.7	13.6	
Antiaging agent	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Dicumyl peroxide	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.4	1.5	
Specific gravity	1.151	1.151	1.252	1.151	1.151	1.151	1.127	1.151	1.151	1.151	1.044	1.127	—
Surface hardness (JIS-C)[2]	90	91	85	93	94	85	86	90	91	91	78	86	—
Diameter of the core (mm)	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.0	38.4	38.4	—
Cover, Composition (wt. parts): Ionomer resin[3]	100	100	100	100	100	100	100	100	100	100	100	100	—
Titanium dioxide	3	3	3	3	3	3	3	3	3	3	3	3	—
Thickness (mm)	2.2	2.2	2.2	2.2	2.4	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Hardness (shore D)	70	70	70	70	70	70	70	70	70	70	70	70	70
Physical Propertie: Weight of the ball (g)	45.3	45.3	45.4	45.3	45.3	45.4	45.2	45.3	45.3	45.4	45.3	45.3	45.2
Diameter of the ball (mm)	42.70	42.71	42.72	42.71	42.69	42.71	42.72	42.70	42.71	42.72	4	42.71	42.71
Compression of the ball (PGA)	90	105	100	122	125	98	98	104	85	130	90	100	103
Impact resilience index[4)]	100	102	101	102	103	97	97	98	96	99	96	96	100
Shock index[5]	77	85	82	88	90	75	75	89	70	105	70	75	100
Flying distance [Head speed (45 m/s)] (carry m)	211.1	213.2	213.0	214.5	215.1	208.9	209.1	209.9	206.9	210.0	205.1	208.0	210.2
(total m)[6]	223.3	225.4	225.1	226.8	217.7	220.7	221.4	222.0	218.8	222.0	217.3	220.1	222.1
Hitting angle (°)	9.45	9.35	9.37	9.33	9.42	9.25	9.27	9.20	9.21	9.15	9.11	9.27	9.20
Spin (r.p.m.)	2842	2855	2857	2880	2840	2920	2922	2980	2900	3120	3302	2910	3105

*The first-class two-piece golf ball on the market

[1]BR-11 (manufactured by Japan Synthetic Rubber Co., Ltd.)

[2]The hardness is measured with holding the JIS-C type hardness tester vertically to the surface of the core in accordance with JIS-K-6301

[3]The mixture of Surlyn 1605 and Surlyn 1706.

[4]The impact resilience factor calculated from the speed of the core or the ball when the metallic cylinder having a weight of 198.4 g comes into collision with the ball at a speed of 45 m/s and expressed with that in Comparative Example 8 as 100.

[5]The index expressing the maximum shock calculated from the measured change of accerelation of the club with that in Comparative Example 8 as 100.

[6]The ball is hit at a head speed of 45 m/s by means of the swing M/C manufactured by Through Temper Corporation and the flying distance until the spot, where the ball has dropped, is measured as the carry (m) and the flying distance until the spot, where the ball has stopped to roll, is measured as the total (m).

It is found from Comparative Example 1 to 3 and 7 that if the diameter of the inner core is less than 29 mm, the impact resilience is reduced. In addition, it is found from Comparative Example 6 that the impact resilience

is reduced also in the case where the specific gravity of the inner core is larger than that of the outer shell. Furthermore, Comparative Examples 4, 5 indicate that the impact resilience and the flying distance are reduced in the case where the hardness of the inner core at the center thereof is less than 25. In the case where the central hardness if 70 or more, the shock is remarkably increased and thus the feeling is deteriorated.

What is claimed is:

1. A three-piece solid golf ball comprising a solid core consisting of an inner core and an outer shell surrounding said inner core, and a cover covering said solid core, characterized in that the outer diameter of said inner core is 29 to 36 mm, the outer diameter of said solid core is 37 to 41 mm, a central hardness (JIS-C) of the inner core is 25 to 70, a surface hardness (JIS-C) of said outer shell is 80 to 95, a difference between said central hardness of the inner core and said surface hardness of the outer shell is 10 or more, and the relation between the specific gravity of the inner core and the specific gravity of the outer shell satisfies 1.0<a specific gravity of the inner core≦a specific gravity of the outer shell<1.3.

2. The golf ball according to claim 1 wherein said central hardness of the inner core is 40 to 65.

3. The golf ball according to claim 1 wherein said surface hardness of the outer shell is 85 to 92.

* * * * *

EXHIBIT E

US005184828A

United States Patent [19]

[11] Patent Number: 5,184,828

[45] Date of Patent: Feb. 9, 1993

Kim et al.

[54] SOLID THREE-PIECE GOLF BALL

[75] Inventors: Moon K. Kim; In H. Hwang, both of Seoul, Rep. of Korea

[73] Assignee: Ilya Co. Ltd., Seoul, Rep. of Korea

[21] Appl. No.: 699,933

[22] Filed: May 14, 1991

[30] Foreign Application Priority Data

Jun. 1, 1990 [KR] Rep. of Korea 90-8095

[51] Int. Cl.[5] A63B 37/06

[52] U.S. Cl. 273/228; 273/230

[58] Field of Search 273/220, 230, 62, 228, 273/218, 219, 225, 229

[56] References Cited

U.S. PATENT DOCUMENTS

4,570,937 2/1986 Yamata 273/220
4,650,193 3/1987 Molitor et al. .... 273/230 X
4,714,253 12/1987 Nakahara et al. .... 273/230 X
4,781,383 11/1988 Kamata et al. .... 273/230 X
5,002,281 3/1991 Nakahara et al. .... 273/230 X
5,048,838 9/1991 Chikaraishi et al. .... 273/230 X

Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Amster, Rothstein & Ebenstein

[57] ABSTRACT

A non-wound three-piece golf ball which comprises an inner core, an outer layer and a cover, the inner core having a diameter of 23–35 mm and a hardness (Shore D) of 30–62, the outer layer having a diameter of 36–41 mm and a hardness (Shore D) of 30–56, the golf ball having a hardness (Shore D) 46–62 at the outer site in the inner core, which is 11.5–17.5 mm apart from the center of the ball. The golf ball has a maximum hardness (Shore D) in the range of 46–62 at the outer site of the inner core which is located at the interface between the inner core 1 and the outer layer 2 of the golf ball and the hardness then decreases both inwardly and outwardly.

5 Claims, 2 Drawing Sheets

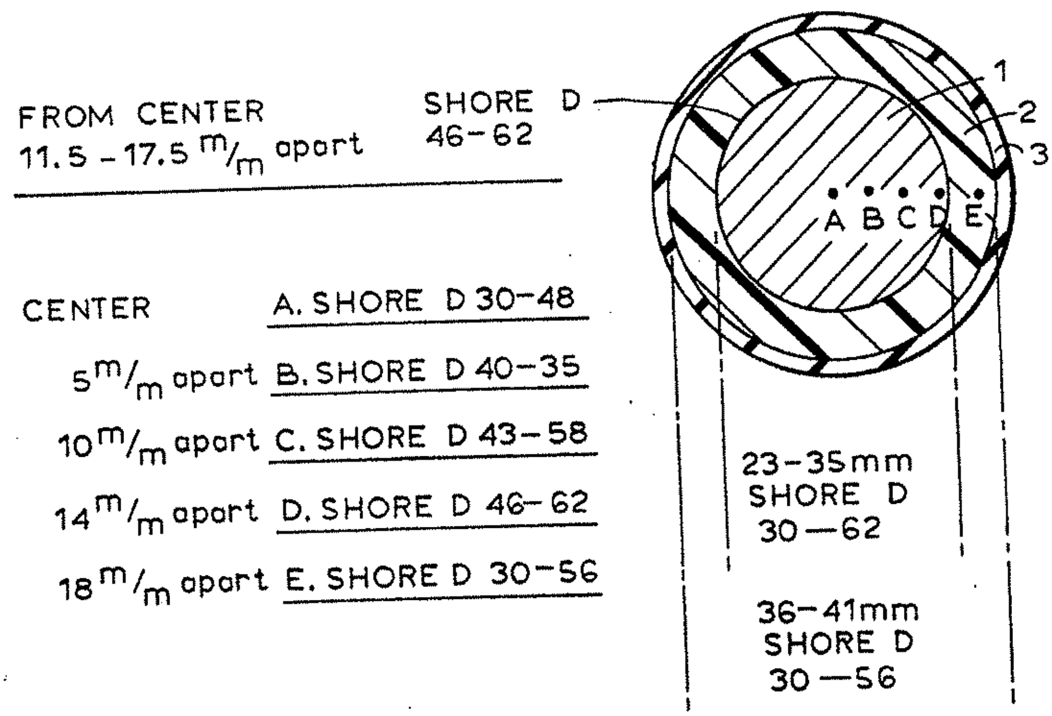
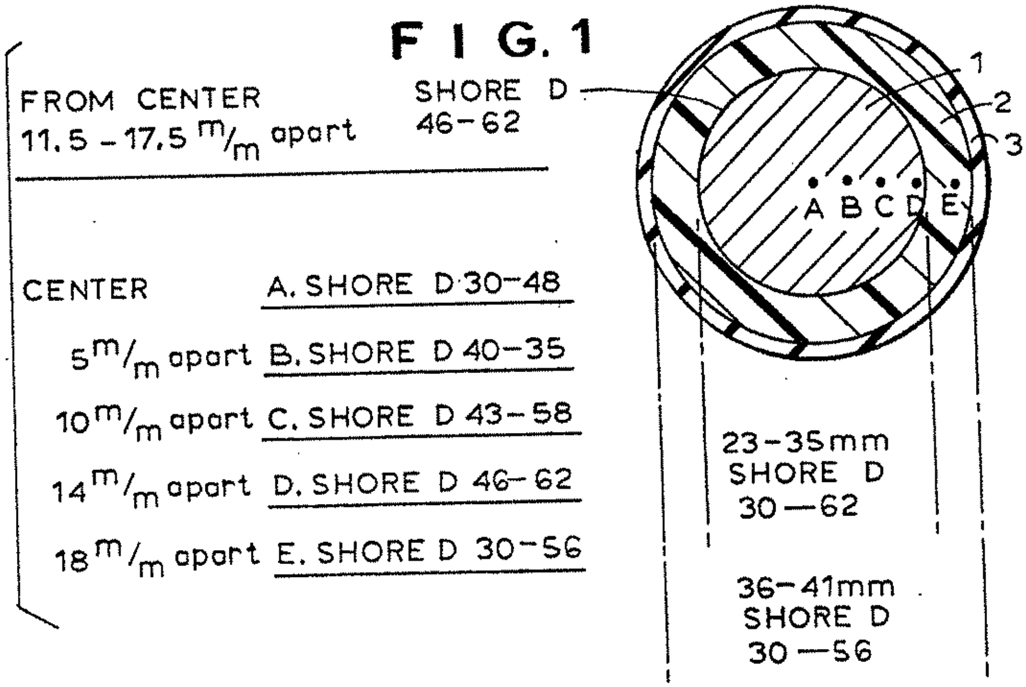


FIG. 1



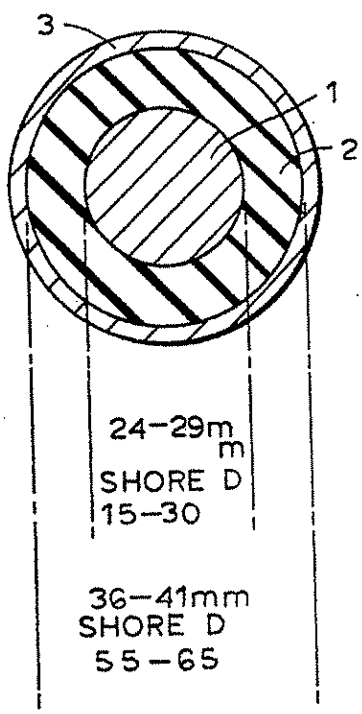
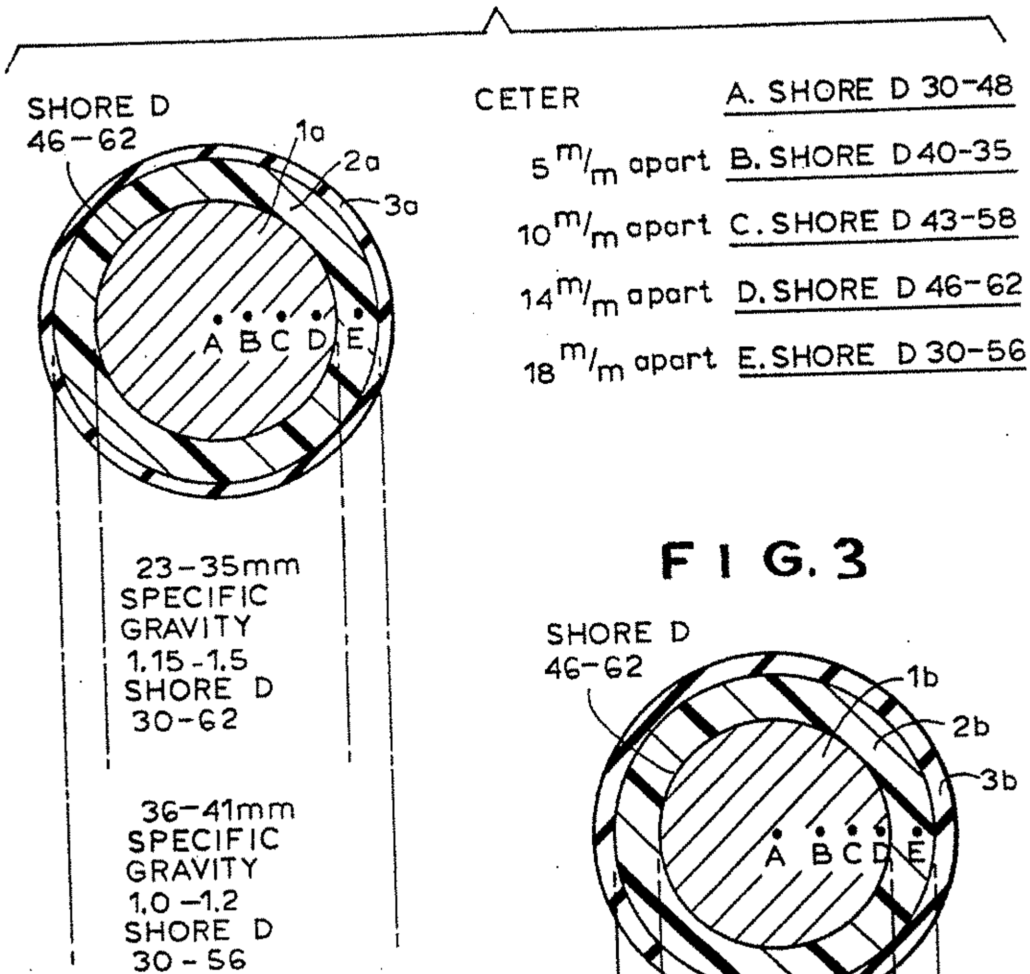


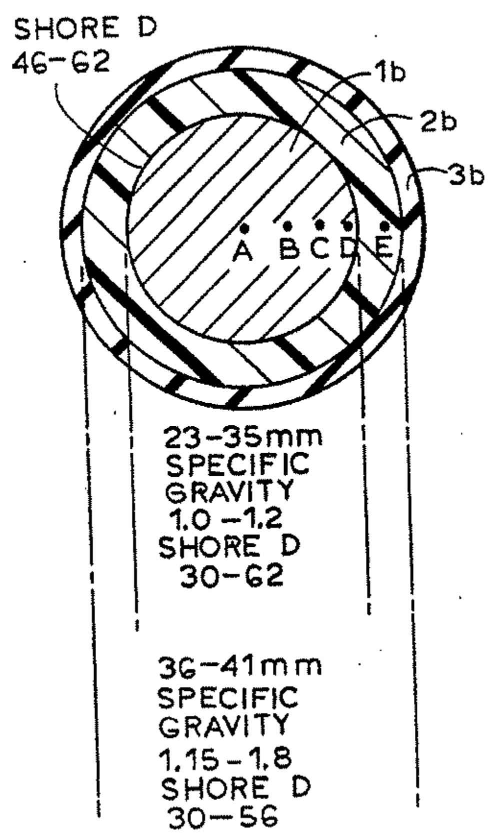
FIG. 4
PRIOR ART

FIG. 2



SHORE D
46-62
1a
2a
3a
A B C D E
23-35mm
SPECIFIC
GRAVITY
1.15-1.5
SHORE D
30-62
36-41mm
SPECIFIC
GRAVITY
1.0-1.2
SHORE D
30-56
CETER
A. SHORE D 30-48
5 m/m apart B. SHORE D 40-35
10 m/m apart C. SHORE D 43-58
14 m/m apart D. SHORE D 46-62
18 m/m apart E. SHORE D 30-56

FIG. 3



SHORE D
46-62
1b
2b
3b
A B C D E
23-35mm
SPECIFIC
GRAVITY
1.0-1.2
SHORE D
30-62
36-41mm
SPECIFIC
GRAVITY
1.15-1.8
SHORE D
30-56

SOLID THREE-PIECE GOLF BALL

The present invention relates to a solid three-piece golf ball having improved rebound characteristics and carry distance while maintaining adequate spin performance. These properties are obtainable by controlling the size of the inner core and outer layer as well as the specific gravity and hardness.

The carry distance and spin performance of a golf ball are very important for the game. Although a solid two-piece ball generally has good rebound characteristics and carry distance, the core is too hard to provide a good spin performance. On the other hand, while a thread wound golf ball generally has a good spin performance, the rebound characteristics and carry distance deteriorate as the wound thread is loosened by prolonged use of the ball.

U.S. Pat. No. 4,781,383 discloses a solid three-piece ball as shown in FIG. 4, which was obtained by controlling the size and hardness of the inner core and the outer layer. This ball has a carry distance similar to that achieved by a solid two-piece ball and feels similar to a conventional thread wound ball. However, this ball has a soft inner core and a hard outer layer. Therefore, it cannot provide a satisfactory carry distance and spin performance.

The total distance achieved by a golf ball includes the carry distance and the run distance. However, the carry distance is very important since the run distance is not accurate due to the unevenness of the ground. The carry distance of a golf ball is directly influenced by its rebound characteristics. Under identical rebound characteristics and aerodynamic conditions (dimple characteristics of the ball), the lifting ability of a ball is improved if the spin rate is increased. Therefore, the peak of the trajectory gets higher, thereby providing an increase in carry distance, as the spin rate increases until the spin rate is increased up to about 2500–3000 RPM, when the ball is struck by a driver.

The present invention provides a solid three-piece golf ball having superior rebound characteristics and carry distance, while maintaining adequate spin rate. These effects are achieved by controlling the sizes, specific gravity and hardness of each part of the solid three-piece golf ball.

In accordance with the present invention there is provided a solid three-piece golf ball comprising a core assembly provided by an inner core 1 and an outer layer 2 and a cover 3 characterized by the following features:

a) the inner core 1 has a diameter in the range 23–35 mm and hardness (Shore D) in the range 30–62;

b) the outer layer 2 has a diameter in the range 36–41 mm and hardness (Shore D) in the range 30–56;

c) the golf ball has a maximum hardness (Shore D) in the range of 46–62 at the outer site of the inner core which is located at the interface between the inner core 1 and the outer layer 2 of the golf ball and the hardness then decreases towards both sides.

Referring to the drawings:

FIG. 1 is a sectional view of a solid three-piece golf ball in accordance with the present invention.

FIG. 2 is a sectional view of a first embodiment (type 1) of the golf ball according to the present invention.

FIG. 3 is a sectional view of a second embodiment (type 2) of the golf ball according to the present invention.

FIG. 4 is a sectional view of the solid three-piece golf ball according to the U.S. Pat. No. 4,781,383.

As shown in FIG. 1, the solid three-piece ball according to the present invention comprises an inner core (1), an outer layer (2) covering the inner core and a cover (3) for protecting the outer layer.

If the surface of the inner core of the solid two-piece ball is soft, the difference between the moduli of elasticity of the inner core and the cover is increased. This generally tends to cause a reduction of rebound coefficient of the ball.

However, it has been found that the rebound characteristics of a solid three-piece golf ball can be improved by controlling the hardness distribution in the outer layer and the inner core in such a way that the golf ball has a maximum hardness at the outer site in the inner core as shown in FIG. 1, which is located at the interface between the inner core and the outer layer of the golf ball, and then the hardness decreases from that site both towards the outer surface of the outer layer and towards the center of the inner core. It has also been found that such a distribution of hardness in the core assembly allows a high energy to accumulate at the interface region where the hardness is maximum. Therefore, when the solid three-piece golf ball according to the present invention is struck by the club, the energy of the club face is efficiently delivered to the maximum hardness region and transferred toward the inner core without loss thus resulting in a high rebound coefficient. It has been observed that the fluctuation of hardness (Shore D) within 2, however, does not adversely affect the efficient transfer of the energy or spin performance of the golf ball of the present invention.

It has been found that the golf ball according to the present invention has adequate spin performance to provide an optimum trajectory resulting in an increase of carry distance since the outer layer is softer than the inner core. Furthermore, the golf ball of the present invention advantageously provides a delayed departure of the golf ball during the putting.

The diameter of the inner core of the golf ball according to the present invention is set to 23–35 mm. If the diameter of the inner core is less than 23 mm, the diameter of the soft outer layer has to be increased and rebound characteristics are adversely affected. On the other hand, if the diameter of the inner core exceeds 35 mm, the diameter of the outer layer has to be decreased, and feeling would be adversely affected due to the hard inner core.

The hardness (Shore D) of the inner core is preferably set in the range of 30–62. A inner core having a hardness (Shore D) less than 30 is too soft to give rebound characteristics necessary for reaching near the initial velocity limitation 250 ft/sec (+2% tolerance) required by U.S.G.A. and R. & A. If the hardness (Shore D) exceeds 62, the feeling of the ball is adversely affected.

The diameter of the outer layer is set to 36–41 mm. If it is less than 36 mm, the carry distance will be decreased due to the increased thickness of the cover. On the other hand, if the diameter of the outer layer is greater than 41 mm, the thickness of the cover will have to be decreased thereby adversely affecting the durability of the ball.

The hardness (Shore D) of the outer layer is set to 30–56 since if the outer layer has a hardness (Shore D) less than 30 it is too soft to provide the rebound characteristics necessary for reaching near the initial velocity

250 ft/sec (+2% tolerance). If the hardness (Shore D) exceeds 56, it is difficult to obtain an adequate spin performance.

The hardness (Shore D) of the outer site in the inner core, which is located near the interface between the inner core and the outer layer, is set to 46–62 because, if the hardness (Shore D) is less than 46, it is not possible to accumulate a high energy, while, if the hardness (Shore D) is greater than 62, the feeling of the ball will be adversely affected.

The first embodiment (type 1) shown in FIG. 2 of the present invention has the following specification:

Inner core

Diameter (mm): 23–35
Specific gravity: 1.15–1.5
Hardness (Shore D): 30–62

Outer layer

Diameter (mm): 36–41
Specific gravity: 1.0–1.2
Hardness (Shore D): 30–56

The outer site in the inner core

Hardness (Shore D): 46–62

The solid three-piece ball of this type provides a superior carry distance even if the cover (3*a*) is made of hard resin since the outer layer (2*a*) is soft and the specific gravity of the inner core is greater than that of the outer layer, which provides an adequate spin performance, when the ball is struck by club, allowing an optimum trajectory and a superior carry distance of the ball. This type of golf ball especially provides a keen back spin when the ball is struck by a short iron.

The second embodiment of the present invention as shown in FIG. 3 has the following specification.

Inner core

Diameter (mm): 23–35
Specific gravity: 1.0–1.2
Hardness (Shore D): 30–62

Outer layer

Diameter (mm): 36–41
Specific gravity: 1.15–1.8
Hardness (Shore D): 30–56

The outer site in the inner core

Hardness (Shore D): 46–62

Generally, the carry distance is decreased if the specific gravity of the outer layer is greater than that of the inner core. However, the solid three-piece ball having the above specification provides a superior carry distance since the outer layer (2*b*) is soft and an adequate spin performance allows an optimum trajectory to be formed, although the cover (3*b*) is made of hard resin. This type of golf ball especially provides a trajectory which is less affected by the wind.

Each of the above two types of solid three-piece golf ball has its own characteristics, and a golfer may choose any type of golf ball depending on the peculiarity of his swing, such as, e.g., club head speed, ability of producing spin, and angle of launching the ball.

The inner core and the outer layer comprises a rubber base, co-cross linking agent, filler, polymerization initiator, antioxidant and the like. As a base rubber, Cis-1, 4 polybutadiene alone may be used. If necessary, natural

rubber, isoprene rubber, and/or styrene-butadiene rubber may be optionally added to 1, 4-polybutadiene.

The co-cross linking agent comprises a compound selected from α,β-ethylenically unsaturated carboxylic acids and metal salts thereof. Trimethylol propane trimethacrylate may be optionally added. Examples of α,β-ethylenically unsaturated carboxylic acids are acrylic acid and methacrylic acid. Metal sats thereof include zinc diacrylate, zinc dimethacrylate, and the like.

The amount of co-cross linking agent used in the inner core is 35–50 parts (weight) for 100 parts (weight) of the base rubber, while the amount of co-cross linking agent used in the outer layer is 25–40 parts (weight).

Fillers which can be used include metal oxides, such as, lead oxide, iron oxide as well as barium sulfate, silica, calcium carbonate and the like. If acrylic acid or methacrylic acid is used, the preferred filler is zinc oxide. The amount of the filler is not limited although it usually depends on the specific gravity or hardness of the inner core or the outer layer to be prepared. The preferred amount of the filler is 1–50 parts (weight) and of the base rubber is 100 parts (weight).

The polymerization initiator includes an organic peroxide, such as, dicumyl peroxide, N-butyl-4, 4'-bis (t-butylperoxy) valerate, bis (t-butylperoxy isopropyl) benzene, 1-1'-bis (t-butylperoxy)-3, 3, 5-trimethyl cyclohexane. The amount of the initiator is 0.2–3.0 parts (weight) of the base rubber is 100 (weight).

If necessary, a coagent such as N-N'-m'-phenelene dimaleimide and the like may be optionally used.

An antioxidizing agent, such as, 2-2'-methylene-bis (4-methyl-6-t-butylphenol) and the like may be added. The amount is preferably 0.5–1.5 parts (weight) of 100 parts (weight) of the base rubber.

The process for preparing the inner core comprises mixing the above components by a conventional mixing apparatus, such as an internal mixer, two roll mill or the like and then subjecting the composition to compression or injection molding.

The compression or injection molding is an important step in the above process, in which the cross linking reaction by the co-cross linking agent takes place with the aid of the initiator under a given temperature and time so as to give the desired hardness distribution in the inner core.

The hardness distribution to be obtained is influenced by the co-cross linking agents and initiators as well as by the temperature and time used for curing.

For each co-cross linking agent, there is an initiator suitable for that co-cross linking agent. The amount of the cross linking agent may be minimized without adversely affecting the hardness distribution when the cross linking reaction is carried out at the reaction temperature, which is 10°–50° C. higher than the decomposition temperature of the initiator used.

If the cross linking reaction takes place at a temperature lower than the above, the distribution of hardness suitable for the present invention cannot be obtained, while, at a temperature higher than the above, a uniform distribution of hardness cannot be obtained.

If the cross linking agent is highly volatile, an initiator with a relatively low decomposition temperature may preferably be used. While the co-cross linking agent is not highly volatile, an initiator having a higher decomposition temperature may preferably be used.

If the cross linking reaction takes place at a higher temperature, the rubber molecules are broken resulting

in remarkable degradation of physical properties of the rubber, such as, the resilience and durability of the rubber, due to severe micro Brown motion and nascent oxygen. Therefore, it is necessary to carry out the cross linking reaction with the aid of an initiator having a decomposition temperature which is 0°-50° C. lower than the boiling point of the co-cross linking agent, α,β-ethylenically unsaturated carboxylic acid.

When an initiator having a relatively low decomposition temperature is used, it is necessary to carry out the cross linking reaction at the temperature which is 20°-50° C. higher than the decomposition temperature for a relatively long time, such as, 10-40 minutes so as to obtain an optimum hardness distribution without adversely affecting other physical properties.

On the other hand, if the initiator with a relatively high decomposition temperature is employed, it is necessary to carry out the cross linking reaction at a temperature which is 10°-40° C. higher than the decomposition temperature for a relatively short period of time, such as, 5-25 minutes.

According to the present invention, the cross linking takes place and the curing of the rubber proceeds when the starting mixture is subjected to heat and pressure predetermined depending on the initiator used. When the heat is transferred through the mixture and rubber is expanded, the co-cross linking agent used is partially evaporated near the metal oxides or salts and the co-cross linking agent in gaseous form migrates from the inner part of the inner core (1) towards the outer part of the inner core carrying out the cross linking reaction of the rubber with the aid of the initiator. Therefore, the cross linking reaction is more active near the outer region of the inner core (1) than at the centre region of the inner core (1) thus resulting in a higher hardness near the outer surface than at the inner region of the core (1).

When the starting mixture is expanded by heating, the mold will be opened unless the mold is prevented from being opened by adding pressure.

Acrylic acid or methacrylic acid form a high molecular weight polymer in the form of matrix having a metal nucleus. The uniformity of cis bonding or cross linking depends on the uniformity of the starting mixture and the heat transfer.

Even after the cross linking is completed, the mixture is continuously expanded by heat until the whole process is completed. It has been found that, due to the pressure added to prevent the opening of the mold, the most dense layers are formed in the region, which is near to the cavity of the mold, namely, the outmost region of the inner core, thus resulting in a gradual increase of the hardness from the centre of the inner core towards the outer part of the inner core forming a maximum hardness site near the interface.

The molecular chains in the most dense layers of the high molecular product are compressed like springs due to the pressure caused by the expansion of the mixture. Therefore, it is possible to store a higher energy.

The outer layer (2) can be prepared by a process similar to that for the inner core (1), although the compression molding as described in the Example is preferred. However, it is important to prevent the outer surface of the outer layer from being too hard so as to obtain the desired hardness distribution as required in the present invention.

However, it is preferred that the crosslinking of the two-piece solid core assembly is carried out at a lower temperature than that for the crosslinking of the inner core to obtain the desired hardness distribution for the present invention.

The starting mixture for preparing the outer layer as well as the solid inner core is also expanded when it is subjected to heating. The expansion in the outer layer is greater than that in the inner core thus resulting in the most dense molecular chains being formed near the interface region between the inner surface of the outer layer and surface of the inner core.

Furthermore, a part of the cross linking agent included in the starting mixture for the outer layer evaporates and the gaseous components formed penetrate into the surface of the inner core rendering a strong binding of the outer layer with the inner core.

The resulting core assembly, which consists of the outer layer and the inner core, has such a hardness distribution that the peak of hardness appears at the outer site in the inner core, which is near the interface between the inner core and the outer layer and that the hardness is gradually decreased toward both sides.

When the ball is struck, it is presumed that the energy given by the club face is efficiently delivered and stored at the site where the hardness is the highest. Then, the energy stored is released toward the inside of the inner core without loss thus resulting in a high rebound coefficient.

The core assembly has a diameter of 36-41 mm and a hardness (Shore D) of 30-62. As mentioned earlier, two types of core assembly are available.

The core assembly is then covered with a resin having a good impact and weather resistance of 0.9-2.6 mm in thickness. The resin may contain inorganic filler, pigment and etc.

As a cover material, balata rubber or ionomer resin (such as "Surlyn" resin marketed by Du Pont Co.) or polyurethane or the like is used, although the ionomer resins are preferred.

The covering is carried out by an injection or compression molding. Finally, the cover is painted to obtain the solid three-piece ball according to the present invention.

As described above, according to the present invention, it is possible to obtain a solid three-piece golf ball of the type (1) or (2) having excellent rebound characteristics and carry distance as well as a high spin performance by adjusting the size and specific gravity as well as the hardness of each of the two pieces forming the core assembly.

The solid three-piece golf ball of the type (1) or (2) according to the present invention provides an excellent carry distance and a better control of the ball compared with a ball having a long roll distance since the golf ball according to the present invention will be least influenced by the ground condition of the field. The golf ball according to the present invention also has an adequate spin performance.

Furthermore, it is possible to control the trajectory of the golf ball of type (1) or (2) using the different moment of inertia of each ball. Therefore, a golfer may select a suitable ball depending on his swing characteristics, such as, his club head speed, spinning ability and launching angle.

EXAMPLE 1

A starting mixture was prepared, which contained Cis-1, 4 polybutadiene rubber (base rubber), zinc diacrylate (co-cross linking agent), zinc oxide (filler), dicu-

myl peroxide (initiator), 2,2'-methylene-bis (4-methyl-6-t-butyl phenol) (antioxidant) in the amounts as indicated in the Table 1.

The mixture was mixed and kneaded by using a two roll mill for 30 minutes and pressure-molded at 165° C. for 10 minutes to prepare a solid inner core.

The inner core was covered by hemispherical pre-mold outer layers in a mold and the resultant product was cured by heating at 150° C. for 20 minutes to obtain a two-piece solid core assembly. This core assembly was then covered by ionomer resin with same dimple design by injection molding and then painted to provide a solid three-piece golf ball according to the present invention.

A solid two-piece golf ball was also prepared exactly in same way as the above.

24 of each type of golf ball were prepared which include the two types of solid three-piece golf ball (1, 2 in the Table 1) and the solid two-piece golf ball (3 in the Table 1). The golf balls were tested by a swing robot at a U.S. testing organization on the same day. The results of the tests are tabulated in the Table 1.

The test club used was 9.5° Driver Steel S. Shaft made by Taylor Made Golf Co. and the head speed was 108 miles/hour. The trajectory was measured through a wire screen within one inch square increments. The range was 0 to 10. The number was recorded at the point which the ball reached its apex. These numbers are for reference only to other balls in the test.

EXAMPLE 2

The starting mixture was prepared, which contained Cis-1, 4 polybutadiene rubber (rubber), zinc diacrylate (co-cross linking agent), zinc oxide (filler), dicumyl peroxide, N-butyl-4,4'-bis (t-butylperoxy) valerate (initiator), 2,2'-methylene-bis (4-methyl-6-t-butyl phenol) (antioxidant) in the amounts as indicated in the Table 2.

Solid three-piece balls were prepared with the process of the Example 1.

The solid three-piece balls (two types) according to the present invention were prepared and tested (1 and 2 in Table 2).

For comparison tests, three-piece solid golf balls commercially available (3 in Table 2) and thread wound balls (4 in Table 2) were also tested. 24 balls for each type of golf balls were used and tested under same method and conditions on the same day. The results of the tests are tabulated in Table 2.

From the Tables 1 and 2, it has been clearly proved that the solid three-piece golf ball according to the present invention has an excellent rebound characteristics, carry distance and an adequate spin performance.

TABLE 1

		Example		Comparative Example
		1	2	3
Starting mixture	Composition of inner core (parts by weight)			
	Cis-1,4 polybutadiene rubber	100	100	100
	zinc diacrylate	43	43	40
	zinc oxide	24.6	4.4	12.1
	dicumyl peroxide (40%)	3	3	3
	2,2',methylene-bis(4-methyl-6-t-butyl phenol)	0.5	0.5	0.5
	Composition of out layer (parts by weight)			
	Cis-1,4 polybutadiene rubber	100	100	
	zinc diacrylate	35	35	
	zinc oxide	5.5	21.5	
	dicumyl peroxide (40%)	3	3	
	2,2'-methylene-bis(4-methyl-6-t-butyl phenol)	0.5	0.5	
	Composition of cover (parts by weight)			
	"Surly 8940" made by Du Pont	100	100	100
	Titanium dioxide	3.1	3.1	3.1
Physical Properties	Inner Core			
	Diameter (mm)	29.7	29.7	
	Weight (gr)	16.5	15	
	Specific gravity	1.20	1.09	
	Outer Core			
	Outer diameter (mm)	38.7	38.7	38.7
	Weight of core assembly (gr)	35.3	35.6	35.3
	Cover			
	Diameter of finished ball (mm)	42.7	42.7	42.7
	Weight of finished ball (gr)	45.3	45.5	45.3
	Distribution of hardness (Shore D)			
	Center	42	42	38
	Site 5 mm apart from center	53	50	47
	Site 10 mm apart from center	54	52	49
	Site 14 mm apart from center	61	58	49
	Site 15 mm apart from center	56	55	49
	Site 16 mm apart from center	55	54	55
	Site 18 mm apart from center	55	54	60
		126	122	122
Characteristics	Carry distance (yds)	242.80	243.23	239.19
	Total distance (yds)	271.61	269.38	267.47
	Velocity (ft/sec)	235.76	234.78	234.48
	Trajectory	5.54	5.52	5.29
		Example		Comparative Example

TABLE 1-continued

		1	2	3	4
Starting mixture	Composition of inner core (parts by weight)				
	Cis-1,4 polybutadiene rubber	100	100		
	zinc diacrylate	38	40		
	zinc oxide	34.2	6		
	dicumyl peroxide (40%)	3	3		
	2,2'-methylene-bis(4-methyl-6-t-butyl phenol)	0.5	0.5		
	Composition of out layer (parts by weight)				
	Cis-1,4 polybutadiene rubber	100	100		
	zinc diacrylate	32	29		
	zinc oxide	3	24.4		
	N-butyl-4,4'-bis(t-butylperoxy)valerate(40%)	3.5	3.5		
	2,2'-methylene-bis(4-methyl-6-t-butyl phenol)	0.5	0.5		
	Composition of cover (parts by weight)				
	"Surly 8940" made by Du Pont	100	100		
	Titanium dioxide	3.1	3.1		
Physical Properties	Inner Core				
	Diameter (mm)	29.7	29.7		
	Weight (gr)	17.1	15.2		
	Specific gravity	1.25	1.11		
	Outer Core				
	Outer diameter (mm)	38.7	38.7	38.3	
	Weight of core assembly (gr)	35.3	35.4	34.7	
	Cover				
	Diameter of finished ball (mm)	42.7	42.7	42.8	42.7
	Weight of finished ball (gr)	45.3	45.3	45.0	45.5
	Distribution of hardness (Shore D)				
	Center	38	39		
	Site 5 mm apart from center	45	46		
	Site 10 mm apart from center	45	47		
	Site 14 mm apart from center	52	53		
	Site 15 mm apart from center	45	39		
	Site 16 mm apart from center	44	38		
	Site 18 mm apart from center	44	38		
		108	104	122	90
Characteristics	Carry distance (yds)	223.12	223.87	213.20	221.79
	Total distance (yds)	253.04	256.12	248.00	251.83
	Velocity (ft/sec)	235.67	235.46	233.41	231.23
	Trajectory	5.26	5.28	4.80	5.12

We claim:

1. A solid three-piece golf ball comprising a core assembly provided by an inner core 1 and an outer layer 2 and a cover 3 characterized by the following features:

a) the inner core 1 has a diameter in the range 23–35 mm and hardness (Shore D) in the range 30–62;

b) the outer layer 2 has a diameter in the range 36–41 mm and hardness (Shore D) in the range 30–56;

c) the golf ball has a maximum hardness (Shore D) in the range of 46–62 at the outer site of the inner core which is located at the interface between the inner core 1 and the outer layer 2 of the golf ball and the hardness then decreases both inwardly and outwardly.

2. A solid three-piece golf ball according to claim 1, in which the specific gravities of the inner core 1 and the outer layer 2 are in the ranges 1.15–1.50 and 1.00–1.20, respectively.

3. A solid three-piece golf ball according to claim 1, in which the specific gravities of the inner core 1 and the outer layer 2 are in the ranges 1.00–1.20 and 1.15–1.80, respectively.

4. A solid three-piece golf ball according to any one of claims 1–3, in which the site of maximum hardness is located 11.5–17.5 mm from the center of the ball.

5. A solid three-piece ball according to any one of claims 1–3 in which the minimum hardness (Shore D) difference between the said outer site in the inner core 1 and the site in the outer layer 2 of the ball is 3.

* * * * *

US005184828A

REEXAMINATION CERTIFICATE (2619th)

United States Patent [19] [11] B1 5,184,828

Kim et al. [45] Certificate Issued Jul. 4, 1995

[54] SOLID THREE-PIECE GOLF BALL

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[73] Assignee: Ilya Co., Ltd., Seoul, Rep. of Korea

Reexamination Request:
No. 90/003,509, Jul. 27, 1994

Reexamination Certificate for:
Patent No.: 5,184,828
Issued: Feb. 9, 1993
Appl. No.: 699,933
Filed: May 14, 1991

[30] Foreign Application Priority Data

Jun. 1, 1990 [KR] Rep. of Korea 90-8095

[51] Int. Cl.[6] A63B 37/06
[52] U.S. Cl. 273/228; 273/230
[58] Field of Search 273/62, 218, 219, 220, 273/225, 228, 229, 230

[56] References Cited

U.S. PATENT DOCUMENTS

4,570,937 2/1986 Yamada 273/220
4,650,193 3/1987 Molitor et al. .... 273/230 X
4,714,253 12/1987 Nakahara et al. .... 273/230 X
4,781,383 11/1988 Kamata et al. .... 273/230 X
4,848,770 7/1989 Shama 273/228
5,002,281 3/1991 Nakahara et al. .... 273/230 X
5,048,838 9/1991 Chikaraishi .... 273/230 X

FOREIGN PATENT DOCUMENTS

63-61029 11/1988 Japan .

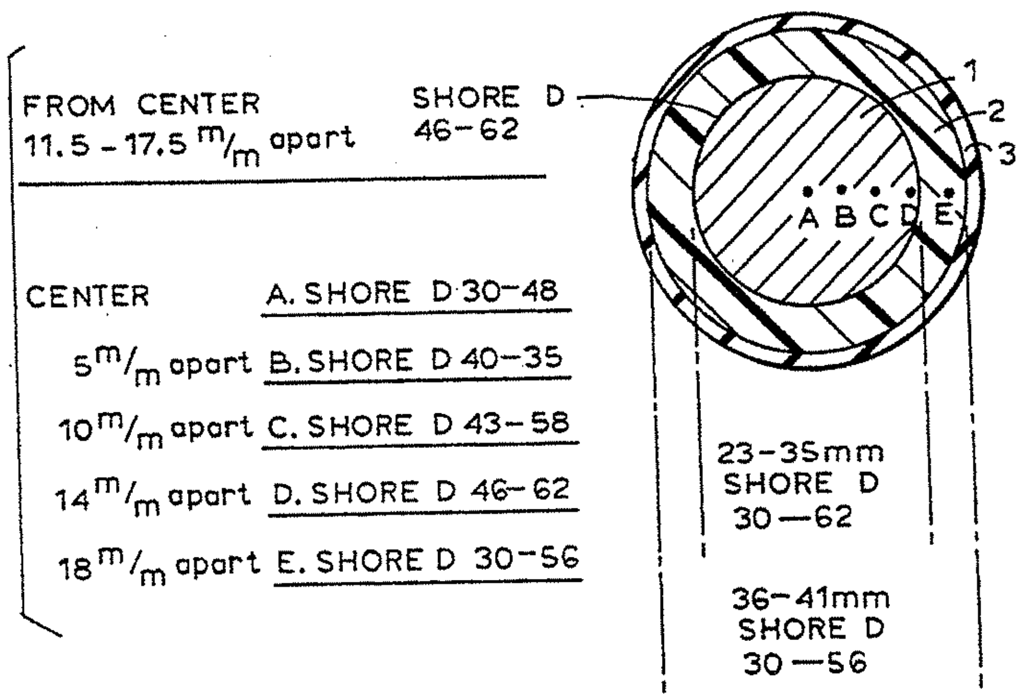
OTHER PUBLICATIONS

JIS-K-6301, 1969.

Primary Examiner—George J. Marlo

[57] ABSTRACT

A non-wound three-piece golf ball which comprises an inner core, an outer layer and a cover, the inner core having a diameter of 23-35 mm and a hardness (Shore D) of 30-62, the outer layer having a diameter of 36-41 mm and a hardness (Shore D) of 30-56, the golf ball having a hardness (Shore D) 46-62 at the outer site in the inner core, which is 11.5-17.5 mm apart from the center of the ball. The golf ball has a maximum hardness (Shore D) in the range of 46-62 at the outer site of the inner core which is located at the interface between the inner core 1 and the outer layer 2 of the golf ball and the hardness then decreases both inwardly and outwardly.



REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

NO AMENDMENTS HAVE BEEN MADE TO THE PATENT

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1-5** is confirmed.

* * * * *

EXHIBIT F

US005711723A

United States Patent [19]
Hiraoka et al.

[11] Patent Number: 5,711,723
[45] Date of Patent: Jan. 27, 1998

[54] THREE-PIECE SOLID GOLF BALL

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[21] Appl. No.: **625,813**

[22] Filed: **Apr. 4, 1996**

[30] **Foreign Application Priority Data**

Apr. 5, 1995 [JP] Japan 7-106909

[51] **Int. Cl.**[6] **A63B 37/06**; A63B 37/14
[52] **U.S. Cl.** 473/374; 473/378
[58] **Field of Search** 473/374, 378

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,714,253 12/1987 Nakahara et al. 473/374

FOREIGN PATENT DOCUMENTS

0625363 11/1994 European Pat. Off. .
2232162 4/1990 United Kingdom .

Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch, LLP

[57] **ABSTRACT**

A three-piece solid golf ball which attains a long flight distance with excellent controllability which comprises a core having a two-layer structure of a center and a shell covering the center, and a cover covering the core, wherein

the center has a diameter of 25 to 37 mm, a JIS-C hardness of 60 to 85 at its center point, and a JIS-C hardness difference between the center point and a surface of the center of not more than 4,

the shell has a JIS-C surface hardness of 75 to 90, and

the cover has a stiffness modulus of 1,200 to 3,600 kg/cm^2, with; the hardness being measured by a JIS-C type hardness tester.

3 Claims, 1 Drawing Sheet

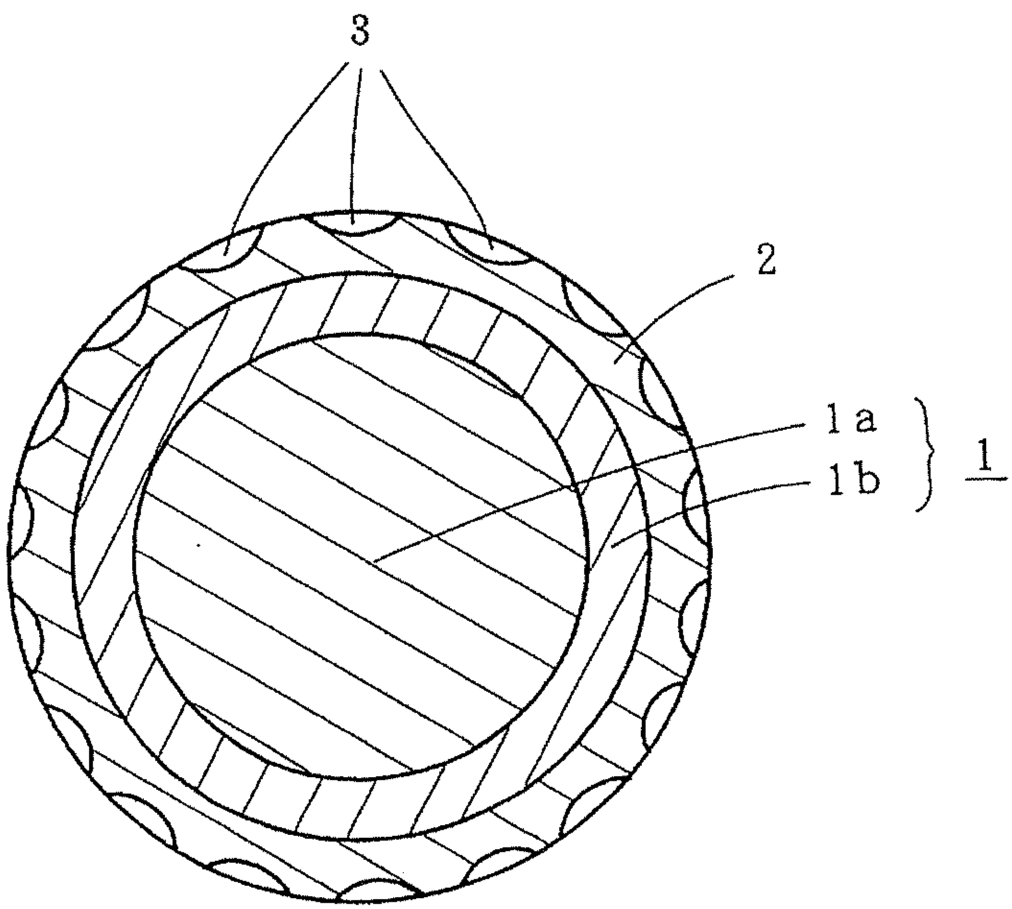
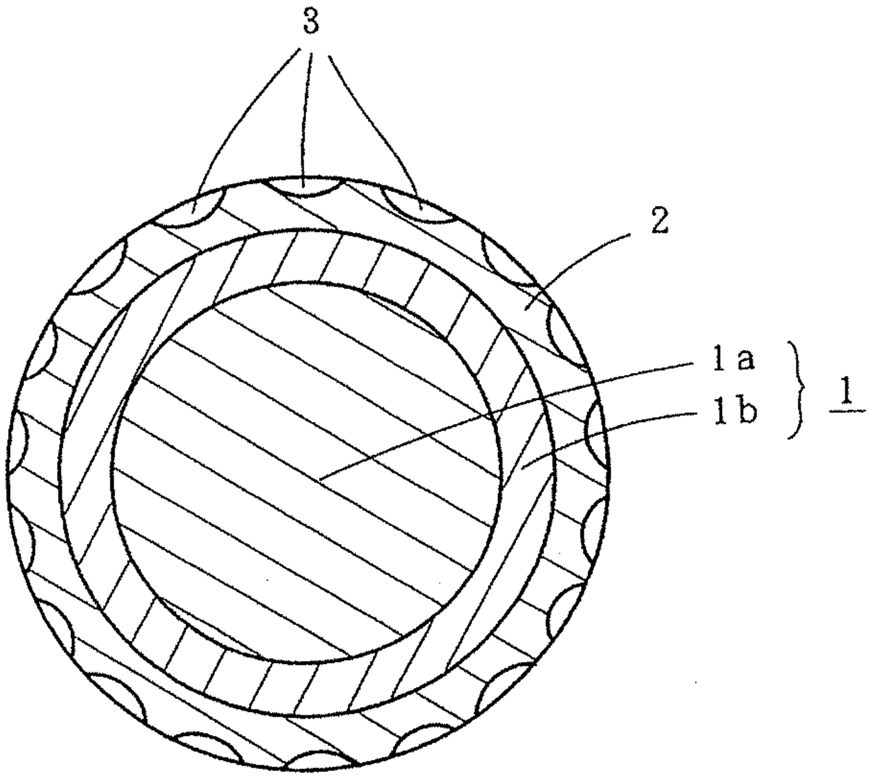


Fig. 1



THREE-PIECE SOLID GOLF BALL

FIELD OF THE INVENTION

The present invention relates to a three-piece solid golf ball comprising a core having a two-layer structure consisting of a center and a shell covering the center, and a cover covering the core.

BACKGROUND OF THE INVENTION

Golf balls which are commercially available at present can be classified roughly into a solid golf ball and a thread wound golf ball. The solid golf ball includes golf balls having a one-, two- and three-layer structure. Regarding a solid golf ball having a two- or three-layer structure, there has been intensively developed a golf ball which can readily stop at the time of landing. This is generally conducted by softening the cover and increasing the spin amount when hitting the ball with a short iron. In other words, controllability of a golf ball is considered to be important factor.

However, when the cover is softened to increases the spin amount and impart good controllability, it adversely lowers the rebound characteristics of the golf ball and decreases flight distance.

OBJECTS OF THE INVENTION

A main object of the present invention is to provide a solid golf ball which satisfies both long flight distance and controllability characteristics. In other words, the main object of the present invention is to provide a solid golf ball which attains a long flight distance when hit by a driver, and attains an effective amount of spin when hit by a short iron near the green to deadly stop (excellent controllability).

This object as well as other objects and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the accompanying drawing.

BRIEF EXPLANATION OF DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

FIG. 1 is a schematic cross section illustrating one embodiment of the three-piece solid golf ball of the present invention.

SUMMARY OF THE INVENTION

The present invention provides a three-piece solid golf ball which comprises a core having a two-layer structure consisting of a center and a shell covering the center, and a cover covering the core, wherein

the center has a diameter of 25 to 37 mm, a JIS-C hardness of 60 to 85 at its center point, and a JIS-C hardness difference between the center point and a surface of not more than 4,

the shell has a JIS-C surface hardness of 75 to 90, and

the cover is composed of a cover composition having a stiffness modulus of 1,200 to 3,600 kg/cm^2; the hardness being measured by a JIS-C type hardness tester.

DETAILED DESCRIPTION OF THE INVENTION

According to the present invention, rebound characteristics are enhanced and the flight distance is increased when the core is constituted with a two-layer structure comprising a center and a shell, the diameter of the center being 25 to 37 mm, the hardness of the center point of the center having a JIS-C hardness (measured by a JIS-C type hardness tester) of 60 to 85 and the JIS-C hardness difference between the center point of the center and the surface of the center being not more than 4. Also, controllability is improved by forming a cover from a cover composition having a stiffness modulus of 1,200 to 3,600 kg/cm^2, thereby satisfying long flight distance when hit by a driver and good controllability when hit by a short iron.

In the present invention, the center is adjusted to has a diameter of 25 to 37 mm, a JIS-C hardness of 60 to 85 at its center point, and a JIS-C hardness difference between the center point and the surface of the center of not more than 4. When the diameter of the center is smaller than 25 mm, the golf ball is hard and the shot feel is poor. On the other hand, when the diameter of the center exceeds 37 mm, the shell thickness of the shell is made thin, but what the shell thickness is made thin is difficult. Accordingly, the homogeneity of the characteristics of the golf ball deteriorates and the flight performance become unstable. In addition, when the hardness of the center is less than 60, the core is soft and the rebound characteristics deteriorate, which results in a shorter flight distance. On the other hand, when the hardness of the center exceeds 85, the core is too hard and brittle and, therefore, the durability deteriorates. When the hardness difference between the center point and a surface of the center exceeds 4, a large energy loss at the time of hitting is experienced and, therefore, the rebound characteristics deteriorate, which results in shorter flight distances.

In the present invention, it is necessary that the hardness of the surface of the shell (this surface of the shell corresponds to the surface of the core having a two-layer structure comprising (the center and the shell) is controlled to a hardness range of 75 to 90 and the stiffness modulus of the cover composition is 1,200 to 3,600 kg/cm^2. When the surface hardness of the shell is less than 75, the ball compression is small and, therefore, the rebound characteristics deteriorate, which results in a shorter flight distance. On the other hand, when the surface hardness of the shell exceeds 90, the core is too hard and, therefore, the shot feel (feeling at the time of hitting) is poor. In addition, when the stiffness modulus of the cover composition is less than 1,200 kg/cm^2, the rebound characteristics deteriorate, which results in a shorter flight distance. On the other hand, when the stiffness modulus of the cover composition exceeds 3,600 kg/cm^2, the spin amount when hit by a short iron is lowered and the controllability is poor. In the present invention, the stiffness modulus of the cover composition is used in place of the stiffness modulus of the cover. The reason is as follows. That is, once the golf ball is produced, the stiffness modulus of the cover of the golf ball is difficult to measure using a current technique and, therefore, the measurement of the stiffness modulus must be conducted after producing a sample from the cover composition. Accordingly, the stiffness modulus is not determined from the cover of the actual golf ball, but the stiffness modulus of the cover and that of a sample formed from the cover composition are considered to be substantially the same. The stiffness modulus is determined by ASTM D-747.

In the present invention, the surface hardness of the shell is defined to 75 to 90. When the surface hardness of the shell is adjusted to a hardness which is three or more higher than that of the center, all of the shot feel, rebound characteristics and flight performance are improved, and it is particularly preferred.

The center of the core is composed of a crosslinked molded article of a rubber composition. The rubber composition is generally prepared by formulating crosslinking agents, crosslinking initiators, fillers, etc. into a base rubber, and kneading the mixture. In addition, the composition may also contain antioxidants, crosslinking adjustors, softeners etc. if necessary.

The base rubbers can be butadiene rubber having a 85% or more cis-1,4 structure which may be added by other rubbers (e.g. natural rubber, isoprene rubber, styrene-butadiene rubber, etc.)if necessary.

The crosslinking agent can be metal salts of α,β-unsaturated carboxylic acid. Examples of the metal salt of α,β-unsaturated carboxylic acid are one or more metal salts of acrylic acid (e.g. zinc acrylate, magnesium acrylate, etc.) and metal salts of methacrylic acid (e.g. zinc methacrylate, magnesium methacrylate, etc.). Among them, zinc acrylate and zinc methacrylate are particularly preferred. An amount of the metal salt of α,β-unsaturated carboxylic acid as the crosslinking agent is not specifically limited, but preferably 20 to 35 parts by weight, based on 100 parts by weight of the base rubber. In addition, the metal salt of α,β-unsaturated carboxylic acid is formulated in the form of α,β-unsaturated carboxylic acid and metal oxide at the time of formulation. The metal salt of α,β-unsaturated carboxylic acid may be formed while kneading the rubber composition.

Examples of the crosslinking initiators are organic peroxides such as dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, 2,5-dimethyl-2,5-di(t-butylperoxy)hexane, di-t-butyl peroxide, and the like. Among them, dicumyl peroxide is particularly preferred. An amount of the crosslinking initiator is preferably 0.5 to 2.5 parts by weight, based on 100 parts by weight of the base rubber.

Examples of the fillers are inorganic fillers such as zinc oxide, barium sulfate, calcium carbonate, barium carbonate, clay, and the like. An amount of the filler is not specifically limited, but is preferably 20 to 25 parts by weight, based on 100 parts by weight of the rubber.

In case of formulating the crosslinking adjustor, sulfur compounds (e.g. morpholine disulfite, pentachlorothiophenol, diphenyl disulfite, etc.) are used as the crosslinking adjustor. It is preferred that these sulfur compounds are formulated in an amount of about 0.1 to 1.5 parts by weight, based on 100 parts by weight of the base rubber.

The center is produced by subjecting the above rubber composition for center to crosslinking molding according to press molding or injection molding. In case of press molding, the center is generally produced by crosslinking with heating at 140° to 180° C. for 10 to 60 minutes. In case of the injection molding, the center is produced by heating at a die temperature at 135° to 165° C. for 10 to 20 minutes. In addition, the diameter of the center is adjusted to 25 to 37 mm, preferably 28 to 35 mm. The heating when crosslinking molding may also be conducted in two or more stages.

The shell is also produced by subjecting the rubber composition using the same material as that of the center to crosslinking molding. In order to adjust the surface hardness of the shell to 75 to 90, an amount of the metal salt of α,β-unsaturated carboxylic acid as the crosslinking agent is preferably 25 to 35 parts by weight, based on 100 parts by weight of the base rubber. In addition, an amount of the crosslinking initiator is preferably 1 to 3 parts by weight, based on 100 parts by weight of the base rubber.

According to the same manner as that in case of the center, the crosslinking molding for producing the shell is

also conducted by press molding or injection molding. In case of the press molding, a core is produced by molding a pair of semi-spherical half-shells from the rubber composition of the shell, placing a center in the half-shells, followed by crosslink molding in a mold. The crosslink molding is generally conducted at 160° to 180° C. for 10 to 40 minutes. In case of injection molding, there can be used a method comprising preparing a pair of half-shells by a simple boarding, placing a center in the half-shells, followed by press molding to prepare the core. The method comprises producing a pair of semi-vulcanized half-shells in advance by injection molding, placing a center in the half-shells, followed by press molding to prepare a core. In addition, the heating may also be conducted in two or more stages in the crosslink molding of the shell.

A thickness of the shell varies depending on the diameter of the center, but is preferably 1 to 7 mm.

As the cover, various materials can be used. For example, there can be used a cover composition prepared by adding pigments (e.g. titanium dioxide, barium sulfate, etc.) and optionally adding antioxidants to an ionomer resin or a synthetic resin, prepared by adding a polyamide, a polyester, a polyurethane, polyethylene, etc. to the ionomer resin, as the main material.

Examples of the ionomer resins are Hi-milan 1605 (Na), Hi-milan 1706 (Zn), Hi-milan 1707 (Na), Hi-milan AM7315 (Zn), Hi-milan AM7316 (Zn), Hi-milan AM7317 (Zn), Hi-milan AM7318 (Na), Hi-milan MK7320 (K), Hi-milan 1555 (Na) and Hi-milan 1557 (Zn) (trade name, manufactured by Mitsui Du Pont Polychemical Co., Ltd.); Surlyn 8920 (Na), Surlyn 8940 (Na), Surlyn AD8512 (Na), Surlyn 7930 (Li), Surlyn 7940 (Li), Surlyn 9910 (Zn), Surlyn AD8511 (Zn) and Surlyn 9650 (Zn) (trade name, manufactured by Du Pont Co., U.S.A.); and Iotek 7010 (Zn) and Iotek 8000 (Na) (trade name, manufactured by Exxon Chemical Co.). Na, Zn, K, Li, etc., which were described in parenthesis following the trade name of the above ionomer resin, mean neutralizing metal ion species thereof.

In the present invention, the stiffness modulus of the cover composition is also an important characteristic for improving the controllability, and the stiffness modulus of the cover composition is adjusted to 1,200 to 3,600 kg/cm^2, as described above. The stiffness modulus of the cover composition can be adjusted as described above by a selection from the above ionomer resins or a combination thereof.

The molding of the cover is conducted by a method comprising molding the above cover composition into a semi-spherical half-shell in advance, covering the core with two half-shells, followed by pressure molding at 130° to 170° C. for 1 to 15 minutes, or a method comprising injection molding the cover composition directly around the core to cover the core.

The thickness of the cover is generally about 1 to 4 mm. At the time of the cover molding, dimples are optionally formed on the surface of the golf ball. After the cover is molded, painting, stamping, etc. may be optionally provided.

Next, the three-piece solid golf ball of the present invention will be explained with reference to the drawing. FIG. 1 is a schematic cross section illustrating one embodiment of the three-piece solid golf ball of the present invention. In FIG. 1, 1 is a core and the core 1 is composed of an center *1a* and an shell *1b* formed around the center, and 2 is a cover for covering the above core 1.

The center *1a* is composed of an crosslinked molded article of the rubber composition. The diameter of the center

is 25 to 37 mm, the JIS-C hardness of the center of the center is within the range of 60 to 85 and the JIS-C hardness difference between the center point and a surface of the center is not more than 4. The shell *1b* is composed of a crosslinked molded article of the rubber composition formed around the center *1a*, and the surface hardness is within the range of 75 to 90. In addition, the cover is made of the cover composition having a stiffness modulus of 1,200 to 3,600 kg/cm^2 and preferably has a Shore D hardness of 59 to 70. When the cover composition has a Shore D hardness of less than 59, the golf ball has poor rebound characteristics and shorter flight distance. When it is more than 70, the ball has poor shot feel and poor controllability. The core 1 having a two-layer structure of the center *1a* and shell *1b* is covered with the cover.

The number 3 indicates dimples and suitable number/embodiment of dimples 3 may be optionally provided on the cover 2 so as to obtain the desired characteristics. In addition, painting, marking, etc. may be optionally provided on the surface of this three-piece solid golf ball.

As described above, according to the present invention, there could be provided a three-piece solid golf ball which attains long flight distance and is superior controllability.

EXAMPLES

The following Examples and Comparative Examples further illustrate the present invention in detail but are not to be construed to limit the scope thereof.

Examples 1 to 6 and Comparative Examples 1 to 6

According to the formulation shown in Tables 1 to 3, a rubber composition for center was prepared, respectively. The resulting rubber composition for center was charged in a mold for center and subjected to crosslinking molding under the condition shown in Tables 1 to 3 to produce an center. The diameter and hardness of the resulting center were measured. The results are shown in Tables 1 to 3. Further, the unit of the amount of the respective components to be formulated is "parts by weight," and the same may be said of the tables showing the formulation described hereinafter. The hardness of the center was measured at the center of the center, position which is 5 mm away from the center to surface, position which is 10 mm away from the center to surface, position which is 15 mm away from the center to surface, and surface, using a JIS-C type hardness tester. Further, the hardness of the interior of the center such as that of the center of the center was determined by cutting the center into halves, followed by measuring at the predetermined position, respectively.

The center formulation, diameter of the center, crosslinking condition and hardness of the center of Examples 1 to 6 are shown in Table 1. Those of comparative, Examples 1 to 3 are shown in Table 2, and those of Comparative Examples 4 to 6 are shown in Table 3. Further, the butadiene rubber used for preparing the rubber composition for center is BR-11 (trade name) manufactured by Japan Synthetic Rubber Co., Ltd., and the cis-1,4 structure content of this butadiene rubber is 96%. The antioxidant used is Noclak NS-6 (trade name) manufactured by Ohuchi Shinko Kagaku Kogyo Co., Ltd. Those in which the crosslinking condition is described in two stages indicate that the heating for crosslinking molding is conducted in two stages. Regarding those having no measuring point of the hardness at the predetermined position because of small diameter of the center, the hardness is not shown as a matter of course.

TABLE 1

	Example No.					
	1	2	3	4	5	6
Formulation of center						
Butadiene rubber	100	100	100	100	100	100
Zinc acrylate	27	30	27	27	27	27
Zinc oxide	18.9	17.8	18.9	18.9	18.9	18.9
Antioxidant	0.5	0.5	0.5	0.5	0.5	0.5
Dicumyl peroxide	1.2	1.2	1.2	1.2	1.2	1.2
Diameter of center (mm)	35	35	35	27	30	32
Crosslinking condition (°C. × minutes)	140 × 30 165 × 25	140 × 30 165 × 25	140 × 30 165 × 25	140 × 30 165 × 25	140 × 30 165 × 25	140 × 30 165 × 25
Hardness of center						
Center point	76	80	75	75	74	75
Position which is 5 mm away from the center point	76	80	74	74	73	74
Position which is 10 mm away from the center point	74	79	74	73	74	75
Position which is 15 mm away from the center point	76	80	73	—	—	74
Surface	77	79	73	75	74	75

TABLE 2

	Comparative Example No.		
	1	2	3
Formulation of center:			
Butadiene rubber	100	100	100
Zinc acrylate	25	23	30
Zinc oxide	19.6	20.4	17.8
Antioxidant	0.5	0.5	0.5
Dicumyl peroxide	1.5	1.5	1.2
Diameter of center: (mm)	35	35	20
Crosslinking condition (°C. × minutes)	165 × 25	150 × 25	140 × 33 165 × 25
Hardness of center			
Center point	58	55	82
Position which is 5 mm away from the center point	61	55	81
Position which is 10 mm away from the center point	63	56	—
Position which is 15 mm away from the center point	68	58	—
Surface	75	59	80

TABLE 3

	Comparative Example No.		
	4	5	6
Formulation of center:			
Butadiene rubber	100	100	100
Zinc acrylate	30	27	27
Zinc oxide	17.8	18.9	18.9
Antioxidant	0.5	0.5	0.5

TABLE 3-continued

	Comparative Example No.		
	4	5	6
Dicumyl peroxide	1.2	1.2	1.2
Diameter of center (mm)	38	27	27
Crosslinking condition (°C. × minutes)	140 × 30 165 × 25	140 × 30 165 × 25	140 × 30 160 × 25
Hardness of center			
Center point	79	75	75
Position which is 5 mm away from the center point	80	74	74
Position which is 10 mm away from the center point	81	73	73
Position which is 15 mm away from the center point	80	—	—
Surface	81	75	75

Next, a rubber composition for shell was prepared according to the formulation shown in Tables 4 to 6 and a pair of semi-vulcanized half-shells were molded from the rubber composition for shell. Then, the composition was covered on the above center and subjected to crosslinking molding in a die under the crosslinking condition shown in Tables 4 to 6 to produce a core having a diameter of 39 mm. The surface hardness of the resulting core (i.e. surface hardness of the shell) was measured by a JIS-C type hardness tester. The results are shown in Tables 4 to 6. Regarding Comparative Example 4, the diameter of the center is too large and, therefore, the thickness of the shell is thin and scatter in thickness is too large, thereby making it impossible to conduct a proper evaluation of characteristics. Accordingly, the surface hardness of the core was not measured and, therefore, the measuring results of the surface hardness of the core of Comparative Example 4 are not shown in Table 6. In addition, the butadiene rubber and antioxidant, which were used for preparing the rubber composition for shell, are the same as those used for preparing the center.

TABLE 4

	Example No.					
	1	2	3	4	5	6
Formulation of shell						
Butadiene rubber	100	100	100	100	100	100
Zinc acrylate	31	31	25	31	31	30
Zinc oxide	17.5	17.5	19.7	17.5	17.5	17.5
Antioxidant	0.5	0.5	0.5	0.5	0.5	0.5
Dicumyl peroxide	2.0	2.0	2.0	2.0	2.0	2.0
Crosslinking condition (°C. × minutes)	165 × 15	165 × 15	165 × 15	165 × 20	165 × 15	165 × 15
Surface hardness of core	84	84	78	87	83	82

TABLE 5

	Comparative Example No.		
	1	2	3
Formulation of shell			
Butadiene rubber	100	100	100
Zinc acrylate	31	20	31
Zinc oxide	17.5	21.5	17.5
Antioxidant	0.5	0.5	0.5
Dicumyl peroxide	2.0	1.2	3.0
Crosslinking condition (°C. × minutes)	165 × 20	165 × 20	165 × 15
Surface hardness of core	84	63	84

TABLE 6

	Comparative Example No.		
	4	5	6
Formulation of shell			
Butadiene rubber	100	100	100
Zinc acrylate	31	31	31
Zinc oxide	17.5	17.5	17.5
Antioxidant	0.5	0.5	0.5
Dicumyl peroxide	2.0	2.0	2.0
Crosslinking condition (°C. × minutes)	165 × 15	165 × 20	165 × 20
Surface hardness of core	—	87	87

Then, cover compositions A to G were prepared according to the formulation shown in Table 7, and the stiffness modulus of the resulting cover compositions was measured, respectively. The results are shown in Table 7. Further, the stiffness modulus of the cover composition was measured as follows. That is, the cover composition was subjected to press molding to produce a sheet sample having an thickness of about 2 mm and, after standing at 23° C. (relative humidity: 50%) for two weeks, the stiffness modulus was measured according to ASTM D-747, using a stiffness modulus tester manufactured by Toyo Seiki Co., Ltd.

TABLE 7

	A	B	C	D	E	F	G
Hi-milan 1855*1	75	40	31	90	10	0	0
Hi-milan 1555*2	5	0	10	0	45	6	0
Hi-milan 1706*3	20	30	0	10	45	45	50
Hi-milan 1557*4	0	30	59	0	0	6	0
Hi-milan 1605*5	0	0	0	0	0	44	50
Titanium dioxide	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Stiffness modulus (kg/cm^2)	1500	2000	2500	1000	3000	3500	3700
Cover hardness (Shore D)	60	62	64	57	67	69	72

*1: Hi-milan 1855 (trade name): ethylene-butyl acrylate-methacrylic acid three-dimensional copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 900 kg/cm^2
*2: Hi-milan 1555 (trade name): ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a sodium ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 2,100 kg/cm^2
*3: Hi-milan 1706 (trade name): ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 2,500 kg/cm^2

TABLE 7-continued

	A	B	C	D	E	F	G

*4: Hi-milan 1557 (trade name): ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 2,400 kg/cm²
*5: Hi-milan 1605 (trade name): ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a sodium ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 3,500 kg/cm²

Then, the cover composition thus prepared as described above was injection molded on the above core according to the combination shown in Tables 8 to 10 to form a cover, thereby producing a three-piece solid golf ball having an outer diameter of 42.7 mm. In Tables 8 to 10, the stiffness modulus of the cover composition was shown together with the symbol of the cover composition. Regarding Comparative Example 4, it is impossible to conduct a proper evaluation of characteristics because the difference in thickness is too large when the shell is formed. Therefore, the golf ball was not produced. Accordingly, the stiffness modulus of the cover composition and characteristic values with respect to Comparative Example 4 are not shown in Table 10.

The ball weight, the ball compression due to US PGA system, rebound coefficient, flight distance (carry), spin amount, controllability and shot feel of the resulting golf ball were examined. The results are shown in Tables 8 to 10. Further, the measuring method or evaluation method of the above rebound coefficient, flight distance (carry), spin amount, controllability and shot feel is as follows.

Rebound coefficient:

A metal cylinder (198.4 g) was struck against a golf ball at a speed of 45 m/second using the same initial velocity measuring air gun as one used in R&A (British Golf Society) to measure a ball speed, and then the rebound coefficient was calculated from the ball speed. The larger this value, the higher the rebound characteristics of the golf ball become.

Flight distance:

A driver (No. 1 wood club) was mounted to a Swing robot manufactured by True Temper Co., and then a golf ball was hit at a head speed of 45 m/second to measure a distance to the dropping point as the flight distance.

Spin amount:

A No. 9 iron club was mounted to a Swing robot manufactured by True Temper Co., and then a golf ball was hit with a head speed of 34 m/second. The photograph of the hit golf ball was continuously taken to determine the spin amount.

Controllability:

It is evaluated by practically hitting a golf ball with a sand wedge due to 10 golfers of four professional golfers and six amateur golfers having a handicap of not more than 10. The evaluation criteria are as follows. The results shown in the Tables below are based on the fact that not less than 8 out of 10 professional golfers evaluated with the same criterion.

Evaluation criteria

○: Good
Δ: Ordinary
x: Poor

Shot feel:

It is evaluated by practically hitting a golf ball with a driver (No. 1 wood club) due to 10 golfers of four professional golfers and six amateur golfers having a handicap of not more than 10. The evaluation criteria are as follows. The results shown in the Tables below are based on the fact that not less than 8 out of 10 professional golfers evaluated with the same criterion.

Evaluation criteria

○: Good
Δ: Ordinary
x: Poor

TABLE 8

	Example No.					
	1	2	3	4	5	6
Stiffness modulus of cover composition (kg/cm²)	1500 A	2000 B	2500 C	1500 A	3000 E	3500 F
Ball weight (g)	45.24	45.41	45.35	45.23	45.28	45.31
Ball compression (USGA)	90	100	95	97	102	104
Rebound coefficient	0.7524	0.7612	0.7600	0.7589	0.7626	0.7635
Flight distance (yard)	223	226	224	223	223	226
Spin amount (rpm)	7410	7200	7010	7370	7010	6950
Controllability	○	○	○	○	○	○
Shot feel	○	○	○	○	○	○
Overall evaluation	○	○	○	○	○	○

TABLE 9

	Comparative Example No.		
	1	2	3
Stiffness modulus of cover composition (kg/cm²)	2000 B	2000 B	2000 B
Ball weight (g)	45.32	45.31	45.33
Ball compression (USGA)	87	50	111
Rebound coefficient	0.7400	0.7324	0.7630
Flight distance (yard)	214	210	222
Spin amount (rpm)	7000	6540	7000
Controllability	Δ	X	X
Shot feel	Δ	X	X
Overall evaluation	X	X	X

TABLE 10

	Comparative Example No.		
	4	5	6
Stiffness modulus of cover composition (kg/cm²)	A golf ball was not produced.	1000 D	3700 G
Ball weight (g)	—	45.25	45.23
Ball compression (USGA)	—	90	109
Rebound coefficient	—	0.7365	0.7645
Flight distance (yard)	—	212	226
Spin amount (rpm)	—	7730	6400
Controllability	—	Δ	X
Shot feel	—	Δ	X
Overall evaluation	—	X	X

As is apparent from a comparison between ball characteristics of Examples 1 to 6 shown in Table 8 and those of Comparative Examples 1 to 3 and Comparative Example 5 to 6 shown in Tables 9 to 10, the golf balls of Examples 1 to 6 attained large flight distance and large spin amount and were superior in controllability and shot feel.

To the contrary, regarding the golf ball of Comparative Example 1, the hardness of the center of the center is low and hardness difference between the center and surface of the center is large and, therefore, the rebound characteristics deteriorate which decrease the flight distance. In addition, the controllability and shot feel were not good. Regarding the golf ball of Comparative Example 2, the hardness of the center of the center and that of the surface of the shell are too low and, therefore, the rebound characteristics deteriorate which decrease the flight distance. In addition, the shot feel was also heavy and poor. Regarding the golf ball of Comparative Example 3, the diameter of the center is small and, therefore, the golf ball is hard, which results in poor shot feel and controllability.

Regarding the golf ball of Comparative Example 5, the stiffness modulus of the cover is small and, therefore, the rebound characteristics were deteriorated to decrease the flight distance. Regarding the golf ball of Comparative Example 6, the stiffness modulus of the cover is too large and, therefore, both controllability and shot feel were poor. Regarding the golf ball of Comparative Example 4, the diameter of the center is too large as described above and, therefore, variation in thickness of the shell is too large when the shell was formed to produce a core, thereby making it impossible to conduct a proper evaluation of characteristics. Therefore, a golf ball was not produced.

What is claimed is:

1. A three-piece solid golf ball comprising a core having a two-layer structure of a center and a shell covering the center, and a cover covering the core, wherein

the center has a diameter of 25 to 37 mm, a JIS-C hardness of 60 to 85 at its center point, and a JIS-C hardness difference between the center point and a surface of the center of not more than 4,

the shell has a JIS-C surface hardness of 75 to 90, and

the cover has a stiffness modulus of 1,200 to 3,600 kg/cm^2 with the hardness being measured by a JIS-C type hardness tester.

2. The three-piece solid golf ball according to claim 1, wherein the JIS-C surface hardness of the shell is higher than that of the center.

3. The three-piece solid golf ball according to claim 1, wherein the cover has a Shore D hardness of 59 to 70.

* * * * *

EXHIBIT G

US005730663A

United States Patent [19]

Tanaka et al.

[11] Patent Number: 5,730,663

[45] Date of Patent: Mar. 24, 1998

[54] SOLID GOLF BALL

[75] Inventors: **Hiroaki Tanaka**, Kobe; **Keiji Moriyama**, Shirakawa, both of Japan

[73] Assignee: **Sumitomo Rubber Industries, Ltd.**, Hyogo-ken, Japan

[21] Appl. No.: **621,342**

[22] Filed: **Mar. 25, 1996**

[30] **Foreign Application Priority Data**

Mar. 27, 1995 [JP] Japan 6-94335

[51] **Int. Cl.**[6] **A63B 37/06**; A63B 37/12

[52] **U.S. Cl.** **473/373**; 473/374; 473/378

[58] **Field of Search** 473/365, 373, 473/374, 378

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,445,387 8/1995 Maruko et al. .... 473/365 X
5,586,950 12/1996 Endo .... 473/373 X

FOREIGN PATENT DOCUMENTS

5-4110 1/1993 Japan .

Primary Examiner—George J. Marlo

[57] **ABSTRACT**

A solid golf ball having high rebound characteristics and being superior in flight performance, durability, controllability, and shot feel which comprises a core and a cover covering the core, wherein the core has a diameter of 32.7 to 38.4 mm and a change of deformation, formed by applying to the core an initial load of 10 kg to a final load of 130 kg, of 3.5 to 6.5 mm, the cover consists of an inner layer and an outer layer in which the inner layer has a stiffness modulus of 3,500 to 6,000 kgf/cm^2 and a thickness of 1.1 to 2.5 mm and the outer layer has a stiffness modulus of 3,000 to 5,500 kgf/cm^2, which is at least 500 kgf/cm^2 lower than that of the inner layer, and a thickness of 1.1 to 2.5 mm, and both the inner layer and outer layer are made of a resinous composition compound mainly of an ionomer resin.

7 Claims, 1 Drawing Sheet

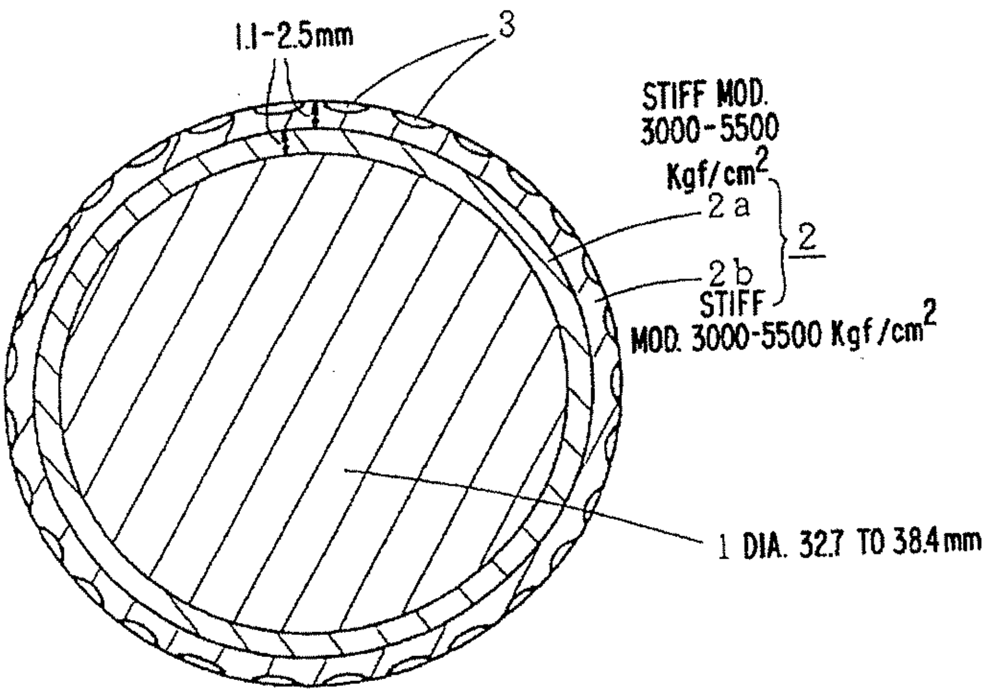
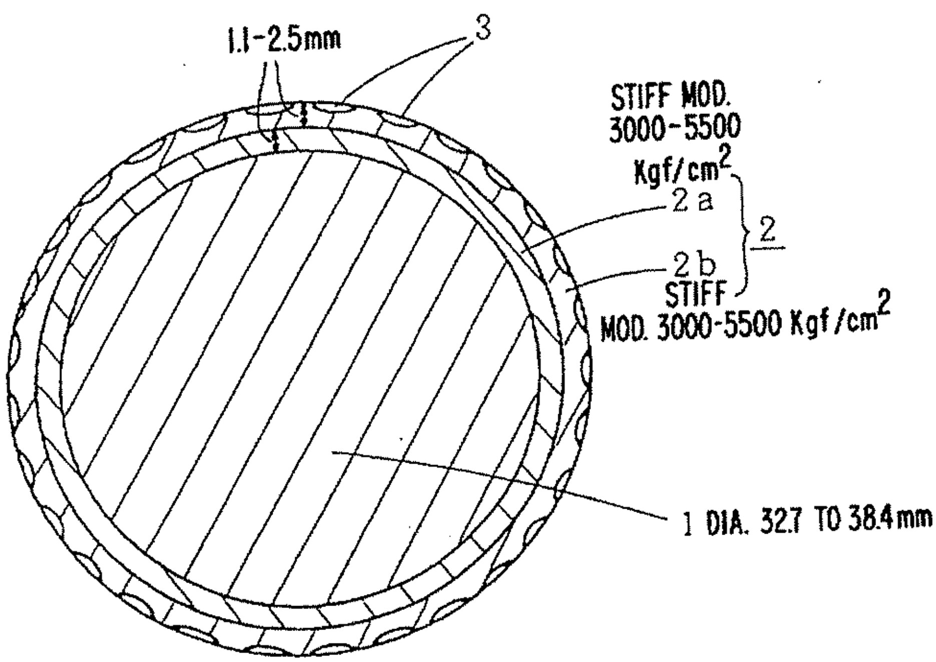


FIG. 1


1.1-2.5mm
3
STIFF MOD.
3000-5500
Kgf/cm2
2a
2
2b
STIFF
MOD. 3000-5500 Kgf/cm2
1 DIA. 32.7 TO 38.4mm

SOLID GOLF BALL

FIELD OF THE INVENTION

The present invention relates to a solid golf ball. More particularly, it relates to a solid golf ball having high rebound characteristics, excellent flight performance, excellent durability, good controllability and good shot feel.

BACKGROUND OF THE INVENTION

Golf balls are roughly classified into a solid golf ball and a thread wound golf ball. The solid golf ball has high rebound characteristics and is superior in flight performance and durability. The thread wound golf ball is superior in controllability and shot feel (feel when hitting).

Among the solid golf ball, a two-piece solid golf ball comprising a core and a cover covering the core is exclusively used because of its excellent flight performance and durability. However, the two-piece solid golf ball has a drawback of poor controllability and poor shot feel in comparison with the thread wound golf ball.

In order to improve the controllability of the two-piece solid golf ball, Japanese Kokoku Publication 5-4110 suggests that the cover of the golf ball is made into two layers which have different stiffness modulus with each other.

However, the method suggested by Japanese Kokoku Publication is applied to a conventionally used two-piece solid golf ball in which its cover is made relatively hard and its core is made relatively soft. The resulting golf ball is composed of a core and a two layered cover covering the core wherein hardness is made harder from the core to the outer layer cover. Accordingly, a deformation stress when hitting is concentrated at the outer layer cover because the outer layer cover is the most hard. Thus, the durability of the golf ball is lowered.

OBJECTS OF THE INVENTION

The main object of the present invention is to solve the above problems of a conventional solid golf ball, thereby providing a solid golf ball having high rebound characteristics, and being superior in flight performance, durability, controllability and shot feel.

This object as well as other objects and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the accompanying drawings.

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

BRIEF EXPLANATION OF DRAWINGS

FIG. 1 is a schematic cross section illustrating one embodiment of the solid golf ball of the present invention.

SUMMARY OF THE INVENTION

The present invention provides a solid golf ball comprising a core and a cover covering the core, wherein the core has a diameter of 32.7 to 38.4 mm and a change of deformation, formed by applying an initial load of 10 kg to a final load of 130 kg to the core, of 3.5 to 6.5 mm. The cover consists of an inner layer cover and an outer layer cover in which the inner layer cover has a stiffness modulus of 3,500 to 6,000 kgf/cm^2 and a thickness of 1.1 to 2.5 mm and the outer layer cover has a stiffness modulus of 3,000 to 5,500 kgf/cm^2, which is at least 500 kgf/cm^2 lower than that of the inner layer cover, and a thickness of 1.1 to 2.5 mm, and both inner layer cover and outer layer cover are made of a resin composition mainly comprising an ionomer resin.

Durability is improved by using the two-layer cover and making the outer layer cover softer than the inner layer cover. Controllability is improved by making the stiffness modulus of the outer layer cover softer than that of the inner layer cover by 500 kgf/cm^2 or more.

DETAILED DESCRIPTION OF THE INVENTION

In the present invention, the reason why the stiffness modulus of the inner layer cover and outer layer cover is set at a specific stiffness modulus, i.e. 3,500 to 6,000 kgf/cm^2 and 3,000 to 5,500 kgf/cm^2, respectively, and the stiffness modulus of the outer layer cover is at least 500 kgf/cm^2 less than that of the inner layer cover, is as follows.

When the stiffness modulus of the inner layer cover is lower than 3,500 kgf/cm^2, the whole cover is too soft and, therefore, the durability is deteriorated. On the other hand, when the stiffness modulus of the inner layer cover exceeds 6000 kgf/cm^2, the feeling at the time of hitting is hard and, therefore, shot feel is inferior. In addition, when the stiffness modulus of the outer layer cover is lower than 3000 kgf/cm^2, the rebound characteristics are deteriorated, which results in a deterioration in the flight performance. On the other hand, when the stiffness modulus of the outer layer cover exceeds 5500 kgf/cm^2, the feeling at the time of hitting is hard and, therefore, shot feel is inferior. When the difference between the stiffness modulus of the inner layer cover and that of the outer layer cover is less than 500 kgf/cm^2, the deformation stress at the time of hitting is concentrated at the outer layer cover, which results in a deterioration of the durability.

In the solid golf ball of the present invention, the core is composed of a crosslinked molded article of a rubber composition. The diameter of the core is 32.7 to 38.4 mm. The thickness of the inner layer cover is 1.1 to 2.5 mm and that of the outer layer cover is 1.1 to 2.5 mm.

When the diameter of the core is smaller than 32.7 mm, rebound characteristics are deteriorated, which results in a deterioration of the flight performance and shot feel. On the other hand, when the diameter of the core exceeds 38.4 mm, the rebound characteristics are likely to be deteriorated, which results in deterioration of flight performance and durability.

When the thickness of the inner layer cover is smaller than 1.1 mm, rebound characteristics are deteriorated, which results in deterioration of flight performance. On the other hand, when the thickness of the inner layer cover exceeds 2.5 mm, the shot feel is inferior. In addition, when the thickness of the outer layer cover is smaller than 1.1 mm, the durability is deteriorated. On the other hand, when the thickness of the outer layer cover exceeds 2.5 mm, the shot feel is inferior.

Also, in the solid golf ball of the present invention, it is necessary that the change of deformation formed by applying a load from 10 kg (initial load) to 130 kg (final load) is 3.5 to 6.5 mm. When the change of deformation formed by applying a load from 10 kg (initial load) to 130 kg (final load) to the core is less than 3.5 mm, the shot feel is inferior because the core is hard. On the other hand, when the change of deformation formed by applying a load from 10 kg (initial load) to 130 kg (final load) to the core exceeds 6.5 mm, the rebound characteristics and durability are inferior because the core is soft.

In the solid golf ball of the present invention, when the inside of said core is measured by a JIS-C type hardness meter, the difference between the hardness at a center of the core and that of the other portions of the core is within the range of 5% or less. That is, when the core has a small difference in hardness, high rebound characteristics and excellent durability can be obtained. On the other hand, when the difference between the hardness at the center and that at the other portion of the core exceeds 5%, the rebound characteristics and durability are liable to deteriorate.

The above core is composed of a crosslinked molded article of a rubber composition obtained by formulating a metal salt of α,β-unsaturated carboxylic acid, an organic peroxide as an initiator, a filler, etc. with cis-1,4-polybutadiene or a base rubber containing cis-1,4-polybutadiene as a main component, and optionally an antioxidant, a stabilizer, etc.

The above cis-1,4-polybutadiene preferably is a so-called high-cis polybutadiene having a cis-1,4 structure of at least 40%, preferably 80% or more. The base rubber is composed of only the above cis-1,4-polybutadiene, or contains the cis-1,4-polybutadiene as the main component. The fact that the base rubber contains the cis-1,4-polybutadiene as the main component means that the base resin is prepared by mixing the above cis-1,4-polybutadiene rubber with another rubber, such as cis-1,4-polyisoprene, styrene-butadiene rubber, ethylene-propylene rubber, ethylene-propylene-diene rubber, chloroprene rubber, etc. It is preferred that the amount of the rubber other than cis-1,4-polybutadiene is not more than 10% by weight.

The metal salt of the α,β-unsaturated carboxylic acid includes one or more salts selected from metal salts of acrylic acid (e.g. zinc acrylate, magnesium acrylate, etc.) and metal salts of methacrylic acid (e.g. zinc methacrylate, magnesium methacrylate, etc.). The amount of the metal salt of the α,β-unsaturated carboxylic acid is preferably 10 to 25 parts by weight, particularly 15 to 20 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the metal salt of the α,β-unsaturated carboxylic acid is less than the above range, the core is soft and the deformation amount of the core is larger than 6.5 mm, which results in a deterioration of the rebound characteristics and flight performance. On the other hand, when the amount of the metal salt of the α,β-unsaturated carboxylic acid exceeds the above range, the deformation amount of the core is smaller than 3.5 mm and the impact force at the time of hitting is large, which results in a deterioration in the shot feel.

The initiator includes organic peroxides such as dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, 2,5-dimethyl-2,5-di(t-butylperoxy) hexane, di-t-butyl peroxide, etc. Among them, dicumyl peroxide is particularly preferred. The amount of the initiator is preferably 0.1 to 5 parts by weight, particularly 0.3 to 3 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the initiator is less than the above range, the crosslinking does not proceed sufficiently and, therefore, sufficient rebound characteristics are not obtained. On the other hand, when the amount of the initiator exceeds the above range, the crosslinking proceeds too much and the core is hard, which results in deterioration of shot feel.

Examples of the filler are zinc oxide, barium sulfate, calcium carbonate, hydrous silicate, etc. An amount of the filler is preferably 1 to 40 parts by weight, particularly 5 to 25 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the filler is less than the above range, the hardness of the core is insufficient. On the other hand, when the amount of the filler exceeds the above range, the specific gravity is too large and, therefore, the rebound characteristics are liable to be deteriorated.

The core can be obtained by charging the above rubber composition in a die for the core, followed by crosslinking. The kneading condition for preparing the rubber composition for the core and crosslinking condition of the composition for core are known to persons skilled in the art, and the crosslinking is normally conducted by heating at the temperature of 140° to 180° C. under pressure for 15 to 55 minutes.

The cover (i.e. inner layer cover and outer layer cover) is formed from a resin composition containing an ionomer resin as the main component. Examples of the ionomer resin are Hi-milan 1605 (Na), Hi-milan 1706 (Zn), Hi-milan 1707 (Na), Hi-milan AM7315 (Zn), Hi-milan AM7316 (Zn), Hi-milan AM7317 (Zn), Hi-milan AM7318 (Na), Hi-milan MK7320 (K), Hi-Milan 1555 (Na) and Hi-milan 1557 (Zn) (trade name, manufactured by Mitsui Du Pont Polychemical Co., Ltd.); Surlyn 8920 (Na), Surlyn 8940 (Na), Surlyn AD8512 (Na), Surlyn 7930 (Li), Surlyn 7940 (Li), Surlyn 9910 (Zn), Surlyn AD8511 (Zn) and Surlyn 9650 (Zn) (trade name, manufactured by Du Pont Co., U.S.A.); and Iotek 7010 (Zn) and Iotek 8000 (Na) (trade name, manufactured by Exxon Chemical Co.). Na, Zn, K or Li which is shown in parenthesis following the trade name of the above ionomer resin, means neutralizing metal ion species thereof. In addition, the composition for inner layer cover and composition for outer layer cover can be prepared by appropriately formulating pigments (e.g. titanium dioxide, barium sulfate, etc.) to the above ionomer resin and optionally formulating an additive (e.g. antioxidant, fluorescent brightener, etc.). In addition, polyolefins (e.g. polyethylene, polypropylene, etc.) and polyamides may be appropriately added unless the characteristics of the ionomer resin are damaged. It is preferred that the amount of the resin to be added is not more than 10% by weight based on the total amount.

A method of covering the inner layer cover and outer layer cover is not specifically limited, but may be a normal method which is used for covering the cover. For example, when the inner layer cover is covered on the core, there can be used a method comprising molding a composition for the inner layer cover into a semi-spherical half-shell in advance, covering a core with two half-shells and then subjecting it to pressure molding at 100° to 170° C. for 1 to 15 minutes, or a method comprising injection molding the composition for the inner layer cover directly on the core to cover the core. In addition, the outer layer cover can be covered on the inner layer cover in the same manner as that of covering the inner layer cover on the core.

One embodiment of the solid golf ball of the present invention will be explained with reference to the accompanying drawing. FIG. 1 is a schematic cross section illustrating one embodiment of the solid golf ball of the present invention. In FIG. 1, 1 is a core, 2 is a cover covering the core. The cover 2 is composed of an inner layer cover 2*a* and an outer layer cover 2*b*. Dimples 3 are provided on the outer layer cover 2*b*.

The core 1 is composed of a crosslinked molded article of a rubber composition which is referred to as a so-called "solid core". The core 1 has a diameter of 32.7 to 38.4 mm and an amount of deformation, formed by applying a load from 10 kg (initial load) to 130 kg (final load) to the core, of 3.5 to 6.5 mm. In addition, it is preferred that the internal hardness of the core 1 is a hardness measured by a JIS-C

type hardness meter and the difference between the hardness at the center part and that at the part other than the center part is not more than 5%.

The inner layer cover 2*a* is composed of a resin composition having a stiffness modulus of 3,500 to 6,000 kgf/cm^2. The inner layer cover 2*a* is composed of a resin composition containing an ionomer resin as a main component, and the thickness is 1.1 to 2.5 mm.

The outer layer cover 2*b* is composed of a resin composition having a stiffness modulus of 3,000 to 5,500 kgf/cm^2, which is at least 500 kgf/cm^2 lower than that of the inner layer cover. The outer layer cover 2*b* is composed of a resin composition containing an ionomer resin as a main component, and the thickness is 1.1 to 2.5 mm.

A suitable number of dimples 3 may be optionally provided in an appropriate arrangement so as to obtain the desired characteristics. Also, painting, marking, etc. may be optionally provided on the surface of the golf ball.

As described above, the present invention could provide a solid golf ball having high rebound characteristics, which is superior in flight performance, durability, controllability and shot feel.

EXAMPLES

The following Examples and Comparative Examples further illustrate the present invention in detail but am not to be construed to limit the scope thereof.

Examples 1 to 5 and Comparative Examples 1 to 5

A composition for core was prepared according to the formulations shown in Tables 1 and 2 and the resulting composition for core was charged in a die for core and crosslinked and molded at 165° C. for 25 minutes to prepare a core, respectively. The diameter, deformation amount and hardness of the resulting core were measured. The results are shown in Tables 1 and 2. Further, the unit of the amount of the respective components to be formulated is "parts by weight", and the same may be said of the tables showing the formulation described hereinafter. The deformation amount of the core was determined by measuring the amount of deformation formed by applying a load from 10 kg (initial load) to 130 kg (final load) to the core. The hardness of the core is measured at the center of the core, position which is 5 mm away from the center to surface, position which is 10 mm away from the center to surface, position which is 15 mm away from the center to surface, and surface, using a JIS-C type hardness tester. Further, the hardness of the interior of the core was determined by cutting the core into halves, followed by measuring at the predetermined position, respectively.

The core formulation, diameter of the core, deformation amount of the core and hardness of the core of Examples 1 to 5 are shown in Table 1. Those of Comparative Examples 1 to 5 are shown in Table 2. Further, those represented by the trade name will be shown in detail, following Table 2.

TABLE 1

	Example No.				
	1	2	3	4	5
Core formulation:					
JSR BR-11 ※1	100	100	100	100	100
Zinc acrylate	26	26	26	26	26
Dicumyl peroxide	1	1	1	1	1
Zinc oxide	32.8	32.8	32.8	29.1	29.1
Diameter of core (mm)	35.1	35.1	35.1	36.3	36.3
Deformation amount of core (mm)	4.335	4.335	4.335	4.300	4.300
Hardness of core:					
Center	71.3	71.3	71.3	71.0	71.0
Position which is 5 mm away from the center	69.5	69.5	69.5	70.5	70.5
Position which is 10 mm away from the center	69.3	69.3	69.3	69.5	69.5
Position which is 15 mm away from the center	69.0	69.0	69.0	70.0	70.0
Surface	67.9	67.9	67.9	69.5	69.5

TABLE 2

	Comparative Example No.				
	1	2	3	4	5
Core formulation:					
JSR BR-11 ※1	100	100	100	100	100
Zinc acrylate	26	26	26	26	26
Dicumyl peroxide	1	1	1	1	1
Zinc oxide	32.8	32.8	32.8	32.8	32.8
Diameter of core (mm)	35.1	35.1	35.1	35.1	35.1
Deformation amount of core (mm)	4.335	4.335	4.335	4.335	4.335
Hardness of core:					
Center	71.3	71.3	71.3	71.3	71.3
Position which is 5 mm away from the center	69.5	69.5	69.5	69.5	69.5
Position which is 10 mm away from the center	69.3	69.3	69.3	69.3	69.3
Position which is 15 mm away from the center	69.0	69.0	69.0	69.0	69.0
Surface	67.9	67.9	67.9	67.9	67.9

※1: JSR BR01 (trade name)

High-cis polybutadiene having 96% of a cis-1,4 structure, manufactured by Japan Synthetic Rubber Co., Ltd.

Then, a composition for inner layer cover and a composition for outer layer cover were prepared according to the formulations shown in Tables 3 and 4. The formulations of the inner layer cover and outer layer cover of Examples 1 to 5 are shown in Table 3, and those of Comparative Examples 1 to 5 are shown in Table 4. Further, the ionomer resin is represented by the trade name but the details will be shown, following Table 4. In addition, the formulations shown in Tables 3 and 4 shows only the resin components, and the composition for inner layer cover and composition for outer layer cover respectively contain titanium dioxide in the amount of 2 parts by weight based on 100 parts by weight of the resin component.

TABLE 3

		Example No.				
		1	2	3	4	5
Inner layer cover formulation (resin component):						
Hi-milan 1706	※2	0	30	0	0	0
Hi-milan 1707	※3	0	30	0	0	0
Hi-milan 1605	※4	0	40	0	0	0
Iotek 8000	※5	50	0	50	50	70
Hi-milan 7315	※6	50	0	50	50	30
Outer layer cover formulation (resin component):						
Hi-milan 1706	※2	30	50	40	30	0
Hi-milan 1707	※3	30	0	30	30	0
Hi-milan 1605	※4	40	50	30	40	0
Iotek 8000	※5	0	0	0	0	50
Hi-milan 7315	※6	0	0	0	0	50

TABLE 4

		Comparative Example No.				
		1	2	3	4	5
Inner layer cover:						
Hi-milan 1706	※2	50	0	30	0	30
Hi-milan 1707	※3	0	0	30	0	30
Hi-milan 1605	※4	50	0	40	0	40
Iotek 8000	※5	0	30	0	30	0
Hi-milan 7315	※6	0	30	0	30	0
Nylon 12		0	40	0	40	0
Outer layer cover:						
Hi-milan 1706	※2	30	40	30	0	30
Hi-milan 1707	※3	0	30	0	0	30
Hi-milan 1605	※4	40	30	40	0	40
Iotek 8000	※5	0	0	30	0	0
Hi-milan 7315	※6	0	0	0	30	0
Hi-milan 1855	※7	30	0	30	0	0
Nylon 12		0	0	0	40	0

※2: Hi-milan 1706 (trade name):

ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 2600 kg/cm^2

※3: Hi-milan 1707 (trade name):

ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a sodium ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 3800 kg/cm^2

※4: Hi-milan 1605 (trade name):

ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a sodium ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 3100 kg/cm^2

※5: Iotek 8000 (trade name):

ethylene-acrylic acid copolymer ionomer resin obtained by neutralizing with a sodium ion, manufactured by Exxon Chemical Co., stiffness modulus: about 4000 kg/cm^2

※6: Hi-milan AM7315 (trade name):

ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 4500 kg/cm^2

※7: Hi-milan 1855 (trade name):

ethylene-methacrylic acid-acrylate three-dimensional copolymer ionomer resin obtained by neutralizing with a zinc ion, manufactured by Mitsui Du Pont Polychemical Co., stiffness modulus: about 900 kg/cm^2

The stiffness modulus of the resin composition for inner layer cover and the resin composition for outer layer cover prepared as described above was shown in Tables 5 and 6. Further, the stiffness modulus was measured at 23° C. using a stiffness modulus tester manufactured by Toyo Seiki Co., Ltd. according to ASTM D-747. A sample for measuring the stiffness modulus was respectively made by subjecting the above resin composition for the inner layer cover and the resin composition for the outer layer cover to hot press molding to form a plate having a thickness of about 2 mm, followed by standing at 23° C. and a relative humidity of 50% for 2 weeks. The resulting sample was used for the measurement.

Then, the resin composition for inner layer cover was injection-molded on the core to form an inner layer cover. The resin composition for the outer layer cover was injection-molded on the inner layer cover to form an outer layer cover. Thus, a solid golf ball having an outer diameter of 42.7 mm and a ball weight of 45.4 g was produced.

The ball weight, ball deformation amount, rebound coefficient, flying distance (carry), spin amount, durability and shot feel of the resulting golf ball were examined. The results are shown in Tables 5 and 6.

The measuring method or evaluation method of the above ball deformation amount, rebound coefficient, flying distance (carry), spin amount, durability and shot feel is as follows.

Ball deformation change

The change of deformation formed by applying a load from 10 kg (initial load) to 130 kg (final load) to a golf ball is measured.

Rebound coefficient:

A metal cylinder (198.4 g) was struck against a golf ball at a speed of 45 m/second using a R & A (British Golf Association) initial velocity measuring device to measure a ball speed, and then the rebound coefficient was calculated from the ball speed.

Flight distance:

A No. 1 wood club was mounted to a Swing robot manufactured by True Temper Co., and then a golf ball was hit at a head speed of 45 m/second to measure a distance to a dropping point as the flight distance (carry).

Spin amount:

A pitching wedge was mounted to a Swing robot manufactured by True Temper Co., and then a golf ball was hit with a head speed of 20 m/second. The photograph of the hit golf ball was continuously taken to determine the spin amount.

Durability:

A golf ball was struck against a metal plate ball at a speed of 45 m/second using an air gun, and then the number of times until breakage was arisen was measured. The resulting value was indicated as an index in case of the value of the golf ball of Example 1 being 100.

Shot feel:

It is evaluated by hitting a golf ball with a No. 1 wood club due to 10 top professional golfers. The evaluation criteria are as follows. The results shown in Tables below are based on the fact that not less than 8 out of 10 professional golfers evaluated with the same criterion about each test item.

Evaluation criteria
○: Excellent
Δ: Ordinary
X: Worse
XX: Worst

TABLE 5

	Example No. 1	2	3	4	5
① Inner layer cover:					
Stiffness modulus (kg/cm^2)	4800	4000	4800	4800	5500
Thickness (mm)	1.9	1.9	1.9	1.6	1.6
② Outer layer cover:					
Stiffness modulus (kg/cm^2)	4000	3000	3600	4000	4800
Thickness (mm)	1.9	1.9	1.9	1.6	1.6
①-② (kg/cm^2)	1000	800	1200	800	700
Ball deformation change (mm)	2.4	2.8	2.5	2.4	2.1
Rebound coefficient	0.792	0.780	0.786	0.795	0.806
Flight distance (yard)	231.5	231.2	230.8	231.3	231.2
Spin amount (rpm)	4500	5000	4800	4900	4500
Durability (index)	100	120	115	105	110
Shot feel	○	○	○	○	○

TABLE 6

	Comparative Example No. 1	2	3	4	5
① Inner layer cover:					
Stiffness modulus (kg/cm^2)	3000	6500	4000	6500	4000
Thickness (mm)	1.9	1.9	1.9	1.9	1.9
② Outer layer cover:					
Stiffness modulus (kg/cm^2)	2000	3600	2000	6500	4000
Thickness (mm)	1.9	1.9	1.9	1.9	1.9
①-② (kg/cm^2)	1000	2900	2000	0	0
Ball deformation amount (mm)	3.0	2.2	2.9	1.8	2.7
Rebound coefficient	0.745	0.755	0.745	0.760	0.760
Flight distance (yard)	226.1	227.2	225.2	227.3	227.0
Spin amount (rpm)	5800	4500	5000	4000	4200
Durability (index)	70	80	80	80	70
Shot feel	Δ	XX	X	XX	Δ

As is apparent from a comparison between ball characteristics of Examples 1 to 5 shown in Table 5 and those of Comparative Examples 1 to 5 shown in Table 6, the golf balls of Examples 1 to 5 had high rebound performance because of large rebound coefficient. In addition, they were superior in flight performance (because of large flight distance), durability (because of large index indicating the durability), controllability (because of large spin amount) and shot feel.

The formulation of the core of the golf balls of Examples 1 to 5 is the same as that of the golf balls of Comparative Examples. In addition, the diameter and deformation amount of the core are the same except for the golf balls of Examples 4 and 5. The golf balls of Examples 1 to 5 has high rebound performance and were superior in flight performance, durability, controllability and shot feel, because the stiffness modulus of the inner layer cover and outer layer cover was specified to a specific stiffness modulus.

To the contrary, the golf ball of Comparative Example 1 was inferior in rebound characteristics, flight distance and durability, because the stiffness modulus of the inner layer cover and the outer layer cover was low. The golf ball of Comparative Example 2 was particularly inferior in shot feel, because the stiffness modulus of the inner layer cover was too high.

The golf ball of Comparative Example 3 was inferior in rebound characteristics, flight distance and durability, because the stiffness modulus of the outer layer cover was low. The golf ball of the Comparative Example 4 was particularly inferior in shot feel, because the stiffness modulus of the inner layer cover and outer layer cover was too high. The golf ball of the Comparative Example 5 was particularly inferior in durability, because there is no difference between the stiffness modulus of the inner layer cover and that of the outer layer cover.

Comparative Examples 6 to 11

A composition for core was prepared according to the formulation shown in Table 7, and then the resulting composition for the core was charged in a die for the core and crosslinked and molded at 165° C. for 25 minutes to produce a core.

The diameter, deformation amount and hardness (measured by JIS-C type hardness tester) of the resulting core were measured in the same manner as that described in Example 1. The results are shown in Table 7. The materials used for the formulation of the core are the same as those used in Example 1, and they were represented by the trade name.

TABLE 7

	Comparative Example No. 6	7	8	9	10	11
Core formulation:						
JSR BR-11 ※1	100	100	100	100	100	100
Zinc acrylate	35	10	26	26	26	26
Dicumyl peroxide	1	1	1	1	1	1
Zinc oxide	30.0	37.7	47.1	27.4	27.4	23.0
Diameter of core (mm)	35.1	35.1	31.7	36.9	36.9	38.7
Deformation amount of core (mm)	3.343	6.600	4.506	4.412	4.412	4.621
Hardness of core:						
Center	76.0	60.0	70.0	70.0	70.0	70.0
Position which is 5 mm away from the center	75.5	60.0	69.5	69.0	69.0	69.0
Position which is 10 mm away from the center	75.5	59.5	69.0	69.5	69.5	69.0
Position which is 15 mm away from the center	76.5	60.5	69.0	69.0	69.0	68.5
Surface	76.5	60.5	69.5	69.5	69.5	68.5

A composition for the inner layer cover and the composition for the outer layer cover were prepared according to the formulations shown in Table 8. According to the manner described in Example 1, the above core was coated with the inner layer composition for the inner layer cover to form an inner layer cover which was coated with the composition for the outer layer cover to form an outer layer cover. Thus, a solid golf ball having an outer diameter of 42.7 mm and a ball weight of 45.4 g was produced. Further, the ionomer resin used for the cover was the same as that used in Examples 1 to 5 and Comparative Example 5, and was represented by the trade name.

The ball deformation amount, rebound coefficient, flight distance (yard), spin amount, durability and shot feel of the resulting golf ball were examined in the same manner as that described in Example 1. The results are shown in Tables 9 and 10. In addition, the stiffness modulus and thickness of the inner layer cover and outer layer cover, which were measured in the same manner as that described in Example 1, are also shown in Tables 9 and 10.

TABLE 8

	Comparative Example No.					
	6	7	8	9	10	11
Inner layer cover formulation (resin component):						
Iotek 8000	50	50	50	50	50	50
Hi-milan 7315	50	50	50	50	50	50
Outer layer cover formulation (resin component):						
Hi-milan 1706	30	30	30	30	30	30
Hi-milan 1707	30	30	30	30	30	30
Hi-milan 1605	40	40	40	40	40	40

TABLE 9

	Comparative Example No.	
	6	7
① Inner layer cover:		
Stiffness modulus (kg/cm^2)	4800	4800
Thickness (mm)	1.9	1.9
② Outer layer cover:		
Stiffness modulus (kg/cm^2)	4000	4000
Thickness (mm)	1.9	1.9
①-② (kg/cm^2)	800	800
Ball deformation change (mm)	2.2	3.3
Rebound coefficient	0.760	0.750
Flight distance (yard)	227.0	226.5
Spin amount (rpm)	4500	4300
Durability (index)	70	30
Shot feel	XX	X

TABLE 10

	Comparative Example No.			
	8	9	10	11
① Inner layer cover:				
Stiffness modulus (kg/cm^2)	4800	4800	4800	4800
Thickness (mm)	2.75	1.0	1.9	1.0
② Outer layer cover:				
Stiffness modulus (kg/cm^2)	4000	4000	4000	4000
Thickness (mm)	2.75	1.9	1.0	1.0
①-② (kg/cm^2)	800	800	800	800
Ball deformation amount (mm)	1.7	2.9	3.0	3.2
Rebound coefficient	0.760	0.755	0.750	0.740
Flight distance (yard)	226.8	226.7	226.3	226.4
Spin amount (rpm)	3800	4000	4400	4600

TABLE 10-continued

	Comparative Example No.			
	8	9	10	11
Durability (index)	100	80	40	20
Shot feel	XX	X	Δ	X

As is apparent from the results shown in Tables 9 and 10, the golf balls of Comparative Examples were inferior in one or more characteristics of flight distance, durability, controllability and shot feel (e.g. small flight distance, etc.).

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A solid golf ball comprising a core and a cover covering said core, wherein the core has a diameter of 32.7 to 38.4 mm and a change of deformation, formed by applying to the core an initial load of 10 kg and a final load of 130 kg, of 3.5 to 6.5 mm, and the cover consists of an inner layer and an outer layer, said inner layer of the cover having a stiffness modulus of 3,500 to 6,000 kgf/cm^2 and a thickness of 1.1 to 2.5 mm and the outer layer cover having a stiffness modulus of 3,000 to 5,500 kgf/cm^2, in which the stiffness modulus of the outer layer is at least 500 kgf/cm^2 lower than that of the inner layer, and a thickness of 1.1 to 2.5 mm, and wherein both the inner layer cover and outer layer cover are made of a resinous composition comprised mainly of an ionomer resin.

2. The solid golf ball according to claim **1**, wherein when the inside of said core is measured by a JIS-C type hardness meter, the difference between the hardness of the center of the core and that of the other portions of the core is within the range of 5% or less.

3. The solid golf ball according to claim **1**, wherein the core is composed of a base rubber comprising at least 80% cis-1,4-polybutadiene.

4. The solid golf ball according to claim **3**, wherein the amount of the base rubber other than cis-1,4-polybutadiene is not more than 10% by weight.

5. The solid golf ball according to claim **1**, wherein the core contains 10 to 25 parts by weight of a metal salt of an α,β-unsaturated carboxylic acid based on 100 parts by weight of the base rubber.

6. The solid golf ball according to claim **5**, wherein the core contains an organic peroxide in an amount of 0.1 to 5 parts by weight based on 100 parts by weight of the base rubber.

7. The solid golf ball according to claim **6**, wherein the core contains a filler in an amount of 1 to 40 parts by weight based on 100 parts by weight of the base rubber.

* * * * *

EXHIBIT H

THIS EXHIBIT HAS BEEN REDACTED IN ITS ENTIRETY

EXHIBIT I

THIS EXHIBIT HAS BEEN REDACTED IN ITS ENTIRETY

EXHIBIT J

Syllabus

NOTE: Where it is feasible, a syllabus (headnote) will be released, as is being done in connection with this case, at the time the opinion is issued. The syllabus constitutes no part of the opinion of the Court but has been prepared by the Reporter of Decisions for the convenience of the reader. See *United States* v. *Detroit Timber & Lumber Co.*, 200 U. S. 321, 337.

SUPREME COURT OF THE UNITED STATES

Syllabus

KSR INTERNATIONAL CO. *v.* TELEFLEX INC. ET AL.

CERTIORARI TO THE UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

No. 04–1350. Argued November 28, 2006—Decided April 30, 2007

To control a conventional automobile's speed, the driver depresses or releases the gas pedal, which interacts with the throttle via a cable or other mechanical link. Because the pedal's position in the footwell normally cannot be adjusted, a driver wishing to be closer or farther from it must either reposition himself in the seat or move the seat, both of which can be imperfect solutions for smaller drivers in cars with deep footwells. This prompted inventors to design and patent pedals that could be adjusted to change their locations. The Asano patent reveals a support structure whereby, when the pedal location is adjusted, one of the pedal's pivot points stays fixed. Asano is also designed so that the force necessary to depress the pedal is the same regardless of location adjustments. The Redding patent reveals a different, sliding mechanism where both the pedal and the pivot point are adjusted.

In newer cars, computer-controlled throttles do not operate through force transferred from the pedal by a mechanical link, but open and close valves in response to electronic signals. For the computer to know what is happening with the pedal, an electronic sensor must translate the mechanical operation into digital data. Inventors had obtained a number of patents for such sensors. The so-called '936 patent taught that it was preferable to detect the pedal's position in the pedal mechanism, not in the engine, so the patent disclosed a pedal with an electronic sensor on a pivot point in the pedal assembly. The Smith patent taught that to prevent the wires connecting the sensor to the computer from chafing and wearing out, the sensor should be put on a fixed part of the pedal assembly rather than in or on the pedal's footpad. Inventors had also patented self-contained modular sensors, which can be taken off the shelf and attached to any

mechanical pedal to allow it to function with a computer-controlled throttle. The '068 patent disclosed one such sensor. Chevrolet also manufactured trucks using modular sensors attached to the pedal support bracket, adjacent to the pedal and engaged with the pivot shaft about which the pedal rotates. Other patents disclose electronic sensors attached to adjustable pedal assemblies. For example, the Rixon patent locates the sensor in the pedal footpad, but is known for wire chafing.

After petitioner KSR developed an adjustable pedal system for cars with cable-actuated throttles and obtained its '976 patent for the design, General Motors Corporation (GMC) chose KSR to supply adjustable pedal systems for trucks using computer-controlled throttles. To make the '976 pedal compatible with the trucks, KSR added a modular sensor to its design. Respondents (Teleflex) hold the exclusive license for the Engelgau patent, claim 4 of which discloses a position-adjustable pedal assembly with an electronic pedal position sensor attached a fixed pivot point. Despite having denied a similar, broader claim, the U. S. Patent and Trademark Office (PTO) had allowed claim 4 because it included the limitation of a fixed pivot position, which distinguished the design from Redding's. Asano was neither included among the Engelgau patent's prior art references nor mentioned in the patent's prosecution, and the PTO did not have before it an adjustable pedal with a fixed pivot point. After learning of KSR's design for GMC, Teleflex sued for infringement, asserting that KSR's pedal system infringed the Engelgau patent's claim 4. KSR countered that claim 4 was invalid under §103 of the Patent Act, which forbids issuance of a patent when "the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art."

Graham v. *John Deere Co. of Kansas City*, 383 U. S. 1, 17–18, set out an objective analysis for applying §103: "[T]he scope and content of the prior art are . . . determined; differences between the prior art and the claims at issue are . . . ascertained; and the level of ordinary skill in the pertinent art resolved. Against this background the obviousness or nonobviousness of the subject matter is determined. Such secondary considerations as commercial success, long felt but unsolved needs, failure of others, etc., might be utilized to give light to the circumstances surrounding the origin of the subject matter sought to be patented." While the sequence of these questions might be reordered in any particular case, the factors define the controlling inquiry. However, seeking to resolve the obviousness question with more uniformity and consistency, the Federal Circuit has employed a "teaching, suggestion, or motivation" (TSM) test, under which a pat-

ent claim is only proved obvious if the prior art, the problem's nature, or the knowledge of a person having ordinary skill in the art reveals some motivation or suggestion to combine the prior art teachings.

The District Court granted KSR summary judgment. After reviewing pedal design history, the Engelgau patent's scope, and the relevant prior art, the court considered claim 4's validity, applying *Graham*'s framework to determine whether under summary-judgment standards KSR had demonstrated that claim 4 was obvious. The court found "little difference" between the prior art's teachings and claim 4: Asano taught everything contained in the claim except using a sensor to detect the pedal's position and transmit it to a computer controlling the throttle. That additional aspect was revealed in, *e.g.*, the '068 patent and Chevrolet's sensors. The court then held that KSR satisfied the TSM test, reasoning (1) the state of the industry would lead inevitably to combinations of electronic sensors and adjustable pedals, (2) Rixon provided the basis for these developments, and (3) Smith taught a solution to Rixon's chafing problems by positioning the sensor on the pedal's fixed structure, which could lead to the combination of a pedal like Asano with a pedal position sensor.

Reversing, the Federal Circuit ruled the District Court had not applied the TSM test strictly enough, having failed to make findings as to the specific understanding or principle within a skilled artisan's knowledge that would have motivated one with no knowledge of the invention to attach an electronic control to the Asano assembly's support bracket. The Court of Appeals held that the District Court's recourse to the nature of the problem to be solved was insufficient because, unless the prior art references addressed the precise problem that the patentee was trying to solve, the problem would not motivate an inventor to look at those references. The appeals court found that the Asano pedal was designed to ensure that the force required to depress the pedal is the same no matter how the pedal is adjusted, whereas Engelgau sought to provide a simpler, smaller, cheaper adjustable electronic pedal. The Rixon pedal, said the court, suffered from chafing but was not designed to solve that problem and taught nothing helpful to Engelgau's purpose. Smith, in turn, did not relate to adjustable pedals and did not necessarily go to the issue of motivation to attach the electronic control on the pedal assembly's support bracket. So interpreted, the court held, the patents would not have led a person of ordinary skill to put a sensor on an Asano-like pedal. That it might have been obvious to try that combination was likewise irrelevant. Finally, the court held that genuine issues of material fact precluded summary judgment.

Held: The Federal Circuit addressed the obviousness question in a narrow, rigid manner that is inconsistent with §103 and this Court's

precedents. KSR provided convincing evidence that mounting an available sensor on a fixed pivot point of the Asano pedal was a design step well within the grasp of a person of ordinary skill in the relevant art and that the benefit of doing so would be obvious. Its arguments, and the record, demonstrate that the Engelgau patent's claim 4 is obvious. Pp. 11–24.

1. *Graham* provided an expansive and flexible approach to the obviousness question that is inconsistent with the way the Federal Circuit applied its TSM test here. Neither §103's enactment nor *Graham*'s analysis disturbed the Court's earlier instructions concerning the need for caution in granting a patent based on the combination of elements found in the prior art. See *Great Atlantic & Pacific Tea Co.* v. *Supermarket Equipment Corp.*, 340 U. S. 147, 152. Such a combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. See, *e.g.*, *United States* v. *Adams*, 383 U. S. 39, 50–52. When a work is available in one field, design incentives and other market forces can prompt variations of it, either in the same field or in another. If a person of ordinary skill in the art can implement a predictable variation, and would see the benefit of doing so, §103 likely bars its patentability. Moreover, if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond that person's skill. A court must ask whether the improvement is more than the predictable use of prior-art elements according to their established functions. Following these principles may be difficult if the claimed subject matter involves more than the simple substitution of one known element for another or the mere application of a known technique to a piece of prior art ready for the improvement. To determine whether there was an apparent reason to combine the known elements in the way a patent claims, it will often be necessary to look to interrelated teachings of multiple patents; to the effects of demands known to the design community or present in the marketplace; and to the background knowledge possessed by a person having ordinary skill in the art. To facilitate review, this analysis should be made explicit. But it need not seek out precise teachings directed to the challenged claim's specific subject matter, for a court can consider the inferences and creative steps a person of ordinary skill in the art would employ. Pp. 11–14.

(b) The TSM test captures a helpful insight: A patent composed of several elements is not proved obvious merely by demonstrating that each element was, independently, known in the prior art. Although common sense directs caution as to a patent application claiming as

innovation the combination of two known devices according to their established functions, it can be important to identify a reason that would have prompted a person of ordinary skill in the art to combine the elements as the new invention does. Inventions usually rely upon building blocks long since uncovered, and claimed discoveries almost necessarily will be combinations of what, in some sense, is already known. Helpful insights, however, need not become rigid and mandatory formulas. If it is so applied, the TSM test is incompatible with this Court's precedents. The diversity of inventive pursuits and of modern technology counsels against confining the obviousness analysis by a formalistic conception of the words teaching, suggestion, and motivation, or by overemphasizing the importance of published articles and the explicit content of issued patents. In many fields there may be little discussion of obvious techniques or combinations, and market demand, rather than scientific literature, may often drive design trends. Granting patent protection to advances that would occur in the ordinary course without real innovation retards progress and may, for patents combining previously known elements, deprive prior inventions of their value or utility. Since the TSM test was devised, the Federal Circuit doubtless has applied it in accord with these principles in many cases. There is no necessary inconsistency between the test and the *Graham* analysis. But a court errs where, as here, it transforms general principle into a rigid rule limiting the obviousness inquiry. Pp. 14–15.

(c) The flaws in the Federal Circuit's analysis relate mostly to its narrow conception of the obviousness inquiry consequent in its application of the TSM test. The Circuit first erred in holding that courts and patent examiners should look only to the problem the patentee was trying to solve. Under the correct analysis, any need or problem known in the field and addressed by the patent can provide a reason for combining the elements in the manner claimed. Second, the appeals court erred in assuming that a person of ordinary skill in the art attempting to solve a problem will be led only to those prior art elements designed to solve the same problem. The court wrongly concluded that because Asano's primary purpose was solving the constant ratio problem, an inventor considering how to put a sensor on an adjustable pedal would have no reason to consider putting it on the Asano pedal. It is common sense that familiar items may have obvious uses beyond their primary purposes, and a person of ordinary skill often will be able to fit the teachings of multiple patents together like pieces of a puzzle. Regardless of Asano's primary purpose, it provided an obvious example of an adjustable pedal with a fixed pivot point, and the prior art was replete with patents indicating that such a point was an ideal mount for a sensor. Third, the

court erred in concluding that a patent claim cannot be proved obvious merely by showing that the combination of elements was obvious to try. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill in the art has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. Finally, the court drew the wrong conclusion from the risk of courts and patent examiners falling prey to hindsight bias. Rigid preventative rules that deny recourse to common sense are neither necessary under, nor consistent with, this Court's case law. Pp. 15–18.

2. Application of the foregoing standards demonstrates that claim 4 is obvious. Pp. 18–23.

(a) The Court rejects Teleflex's argument that the Asano pivot mechanism's design prevents its combination with a sensor in the manner claim 4 describes. This argument was not raised before the District Court, and it is unclear whether it was raised before the Federal Circuit. Given the significance of the District Court's finding that combining Asano with a pivot-mounted pedal position sensor fell within claim 4's scope, it is apparent that Teleflex would have made clearer challenges if it intended to preserve this claim. Its failure to clearly raise the argument, and the appeals court's silence on the issue, lead this Court to accept the District Court's conclusion. Pp. 18–20.

(b) The District Court correctly concluded that when Engelgau designed the claim 4 subject matter, it was obvious to a person of ordinary skill in the art to combine Asano with a pivot-mounted pedal position sensor. There then was a marketplace creating a strong incentive to convert mechanical pedals to electronic pedals, and the prior art taught a number of methods for doing so. The Federal Circuit considered the issue too narrowly by, in effect, asking whether a pedal designer writing on a blank slate would have chosen both Asano and a modular sensor similar to the ones used in the Chevrolet trucks and disclosed in the '068 patent. The proper question was whether a pedal designer of ordinary skill in the art, facing the wide range of needs created by developments in the field, would have seen an obvious benefit to upgrading Asano with a sensor. For such a designer starting with Asano, the question was where to attach the sensor. The '936 patent taught the utility of putting the sensor on the pedal device. Smith, in turn, explained not to put the sensor on the pedal footpad, but instead on the structure. And from Rixon's known wire-chafing problems, and Smith's teaching that the pedal assemblies must not precipitate any motion in the connecting wires,

the designer would know to place the sensor on a nonmoving part of the pedal structure. The most obvious such point is a pivot point. The designer, accordingly, would follow Smith in mounting the sensor there. Just as it was possible to begin with the objective to upgrade Asano to work with a computer-controlled throttle, so too was it possible to take an adjustable electronic pedal like Rixon and seek an improvement that would avoid the wire-chafing problem. Teleflex has not shown anything in the prior art that taught away from the use of Asano, nor any secondary factors to dislodge the determination that claim 4 is obvious. Pp. 20–23.

3. The Court disagrees with the Federal Circuit's holding that genuine issues of material fact precluded summary judgment. The ultimate judgment of obviousness is a legal determination. *Graham*, 383 U. S., at 17. Where, as here, the prior art's content, the patent claim's scope, and the level of ordinary skill in the art are not in material dispute and the claim's obviousness is apparent, summary judgment is appropriate. P. 23.

119 Fed. Appx. 282, reversed and remanded.

KENNEDY, J., delivered the opinion for a unanimous Court.

SUPREME COURT OF THE UNITED STATES

No. 04–1350

KSR INTERNATIONAL CO., PETITIONER *v.* TELEFLEX INC. ET AL.

ON WRIT OF CERTIORARI TO THE UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

[April 30, 2007]

JUSTICE KENNEDY delivered the opinion of the Court.

Teleflex Incorporated and its subsidiary Technology Holding Company—both referred to here as Teleflex—sued KSR International Company for patent infringement. The patent at issue, United States Patent No. 6,237,565 B1, is entitled "Adjustable Pedal Assembly With Electronic Throttle Control." Supplemental App. 1. The patentee is Steven J. Engelgau, and the patent is referred to as "the Engelgau patent." Teleflex holds the exclusive license to the patent.

Claim 4 of the Engelgau patent describes a mechanism for combining an electronic sensor with an adjustable automobile pedal so the pedal's position can be transmitted to a computer that controls the throttle in the vehicle's engine. When Teleflex accused KSR of infringing the Engelgau patent by adding an electronic sensor to one of KSR's previously designed pedals, KSR countered that claim 4 was invalid under the Patent Act, 35 U. S. C. §103, because its subject matter was obvious.

Section 103 forbids issuance of a patent when "the differences between the subject matter sought to be pat-

ented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains."

In *Graham* v. *John Deere Co. of Kansas City*, 383 U. S. 1 (1966), the Court set out a framework for applying the statutory language of §103, language itself based on the logic of the earlier decision in *Hotchkiss* v. *Greenwood*, 11 How. 248 (1851), and its progeny. See 383 U. S., at 15–17. The analysis is objective:

> "Under §103, the scope and content of the prior art are to be determined; differences between the prior art and the claims at issue are to be ascertained; and the level of ordinary skill in the pertinent art resolved. Against this background the obviousness or nonobviousness of the subject matter is determined. Such secondary considerations as commercial success, long felt but unsolved needs, failure of others, etc., might be utilized to give light to the circumstances surrounding the origin of the subject matter sought to be patented." *Id.*, at 17–18.

While the sequence of these questions might be reordered in any particular case, the factors continue to define the inquiry that controls. If a court, or patent examiner, conducts this analysis and concludes the claimed subject matter was obvious, the claim is invalid under §103.

Seeking to resolve the question of obviousness with more uniformity and consistency, the Court of Appeals for the Federal Circuit has employed an approach referred to by the parties as the "teaching, suggestion, or motivation" test (TSM test), under which a patent claim is only proved obvious if "some motivation or suggestion to combine the prior art teachings" can be found in the prior art, the nature of the problem, or the knowledge of a person having ordinary skill in the art. See, *e.g., Al-Site Corp.* v. *VSI*

Int'l, Inc., 174 F. 3d 1308, 1323–1324 (CA Fed. 1999). KSR challenges that test, or at least its application in this case. See 119 Fed. Appx. 282, 286–290 (CA Fed. 2005). Because the Court of Appeals addressed the question of obviousness in a manner contrary to §103 and our precedents, we granted certiorari, 547 U. S ___ (2006). We now reverse.

I

A

In car engines without computer-controlled throttles, the accelerator pedal interacts with the throttle via cable or other mechanical link. The pedal arm acts as a lever rotating around a pivot point. In a cable-actuated throttle control the rotation caused by pushing down the pedal pulls a cable, which in turn pulls open valves in the carburetor or fuel injection unit. The wider the valves open, the more fuel and air are released, causing combustion to increase and the car to accelerate. When the driver takes his foot off the pedal, the opposite occurs as the cable is released and the valves slide closed.

In the 1990's it became more common to install computers in cars to control engine operation. Computer-controlled throttles open and close valves in response to electronic signals, not through force transferred from the pedal by a mechanical link. Constant, delicate adjustments of air and fuel mixture are possible. The computer's rapid processing of factors beyond the pedal's position improves fuel efficiency and engine performance.

For a computer-controlled throttle to respond to a driver's operation of the car, the computer must know what is happening with the pedal. A cable or mechanical link does not suffice for this purpose; at some point, an electronic sensor is necessary to translate the mechanical operation into digital data the computer can understand.

Before discussing sensors further we turn to the me-

chanical design of the pedal itself. In the traditional design a pedal can be pushed down or released but cannot have its position in the footwell adjusted by sliding the pedal forward or back. As a result, a driver who wishes to be closer or farther from the pedal must either reposition himself in the driver's seat or move the seat in some way. In cars with deep footwells these are imperfect solutions for drivers of smaller stature. To solve the problem, inventors, beginning in the 1970's, designed pedals that could be adjusted to change their location in the footwell. Important for this case are two adjustable pedals disclosed in U. S. Patent Nos. 5,010,782 (filed July 28, 1989) (Asano) and 5,460,061 (filed Sept. 17, 1993) (Redding). The Asano patent reveals a support structure that houses the pedal so that even when the pedal location is adjusted relative to the driver, one of the pedal's pivot points stays fixed. The pedal is also designed so that the force necessary to push the pedal down is the same regardless of adjustments to its location. The Redding patent reveals a different, sliding mechanism where both the pedal and the pivot point are adjusted.

We return to sensors. Well before Engelgau applied for his challenged patent, some inventors had obtained patents involving electronic pedal sensors for computer-controlled throttles. These inventions, such as the device disclosed in U. S. Patent No. 5,241,936 (filed Sept. 9, 1991) ('936), taught that it was preferable to detect the pedal's position in the pedal assembly, not in the engine. The '936 patent disclosed a pedal with an electronic sensor on a pivot point in the pedal assembly. U. S. Patent No. 5,063,811 (filed July 9, 1990) (Smith) taught that to prevent the wires connecting the sensor to the computer from chafing and wearing out, and to avoid grime and damage from the driver's foot, the sensor should be put on a fixed part of the pedal assembly rather than in or on the pedal's footpad.

In addition to patents for pedals with integrated sensors inventors obtained patents for self-contained modular sensors. A modular sensor is designed independently of a given pedal so that it can be taken off the shelf and attached to mechanical pedals of various sorts, enabling the pedals to be used in automobiles with computer-controlled throttles. One such sensor was disclosed in U. S. Patent No. 5,385,068 (filed Dec. 18, 1992) ('068). In 1994, Chevrolet manufactured a line of trucks using modular sensors "attached to the pedal support bracket, adjacent to the pedal and engaged with the pivot shaft about which the pedal rotates in operation." 298 F. Supp. 2d 581, 589 (ED Mich. 2003).

The prior art contained patents involving the placement of sensors on adjustable pedals as well. For example, U. S. Patent No. 5,819,593 (filed Aug. 17, 1995) (Rixon) discloses an adjustable pedal assembly with an electronic sensor for detecting the pedal's position. In the Rixon pedal the sensor is located in the pedal footpad. The Rixon pedal was known to suffer from wire chafing when the pedal was depressed and released.

This short account of pedal and sensor technology leads to the instant case.

B

KSR, a Canadian company, manufactures and supplies auto parts, including pedal systems. Ford Motor Company hired KSR in 1998 to supply an adjustable pedal system for various lines of automobiles with cable-actuated throttle controls. KSR developed an adjustable mechanical pedal for Ford and obtained U. S. Patent No. 6,151,976 (filed July 16, 1999) ('976) for the design. In 2000, KSR was chosen by General Motors Corporation (GMC or GM) to supply adjustable pedal systems for Chevrolet and GMC light trucks that used engines with computer-controlled throttles. To make the '976 pedal compatible with the

trucks, KSR merely took that design and added a modular sensor.

Teleflex is a rival to KSR in the design and manufacture of adjustable pedals. As noted, it is the exclusive licensee of the Engelgau patent. Engelgau filed the patent application on August 22, 2000 as a continuation of a previous application for U. S. Patent No. 6,109,241, which was filed on January 26, 1999. He has sworn he invented the patent's subject matter on February 14, 1998. The Engelgau patent discloses an adjustable electronic pedal described in the specification as a "simplified vehicle control pedal assembly that is less expensive, and which uses fewer parts and is easier to package within the vehicle." Engelgau, col. 2, lines 2–5, Supplemental App. 6. Claim 4 of the patent, at issue here, describes:

> "A vehicle control pedal apparatus comprising:
>
> a support adapted to be mounted to a vehicle structure;
>
> an adjustable pedal assembly having a pedal arm moveable in for[e] and aft directions with respect to said support;
>
> a pivot for pivotally supporting said adjustable pedal assembly with respect to said support and defining a pivot axis; and
>
> an electronic control attached to said support for controlling a vehicle system;
>
> said apparatus characterized by said electronic control being responsive to said pivot for providing a signal that corresponds to pedal arm position as said pedal arm pivots about said pivot axis between rest and applied positions wherein the position of said pivot remains constant while said pedal arm moves in fore and aft directions with respect to said pivot." *Id.*, col.

6, lines 17–36, Supplemental App. 8 (diagram numbers omitted).

We agree with the District Court that the claim discloses "a position-adjustable pedal assembly with an electronic pedal position sensor attached to the support member of the pedal assembly. Attaching the sensor to the support member allows the sensor to remain in a fixed position while the driver adjusts the pedal." 298 F. Supp. 2d, at 586–587.

Before issuing the Engelgau patent the U. S. Patent and Trademark Office (PTO) rejected one of the patent claims that was similar to, but broader than, the present claim 4. The claim did not include the requirement that the sensor be placed on a fixed pivot point. The PTO concluded the claim was an obvious combination of the prior art disclosed in Redding and Smith, explaining:

> "'Since the prior ar[t] references are from the field of endeavor, the purpose disclosed . . . would have been recognized in the pertinent art of Redding. Therefore it would have been obvious . . . to provide the device of Redding with the . . . means attached to a support member as taught by Smith.'" *Id.*, at 595.

In other words Redding provided an example of an adjustable pedal and Smith explained how to mount a sensor on a pedal's support structure, and the rejected patent claim merely put these two teachings together.

Although the broader claim was rejected, claim 4 was later allowed because it included the limitation of a fixed pivot point, which distinguished the design from Redding's. *Ibid.* Engelgau had not included Asano among the prior art references, and Asano was not mentioned in the patent's prosecution. Thus, the PTO did not have before it an adjustable pedal with a fixed pivot point. The patent issued on May 29, 2001 and was assigned to Teleflex.

Upon learning of KSR's design for GM, Teleflex sent a

warning letter informing KSR that its proposal would violate the Engelgau patent. "'Teleflex believes that any supplier of a product that combines an adjustable pedal with an electronic throttle control necessarily employs technology covered by one or more'" of Teleflex's patents. *Id.*, at 585. KSR refused to enter a royalty arrangement with Teleflex; so Teleflex sued for infringement, asserting KSR's pedal infringed the Engelgau patent and two other patents. *Ibid.* Teleflex later abandoned its claims regarding the other patents and dedicated the patents to the public. The remaining contention was that KSR's pedal system for GM infringed claim 4 of the Engelgau patent. Teleflex has not argued that the other three claims of the patent are infringed by KSR's pedal, nor has Teleflex argued that the mechanical adjustable pedal designed by KSR for Ford infringed any of its patents.

C

The District Court granted summary judgment in KSR's favor. After reviewing the pertinent history of pedal design, the scope of the Engelgau patent, and the relevant prior art, the court considered the validity of the contested claim. By direction of 35 U. S. C. §282, an issued patent is presumed valid. The District Court applied *Graham*'s framework to determine whether under summary-judgment standards KSR had overcome the presumption and demonstrated that claim 4 was obvious in light of the prior art in existence when the claimed subject matter was invented. See §102(a).

The District Court determined, in light of the expert testimony and the parties' stipulations, that the level of ordinary skill in pedal design was "'an undergraduate degree in mechanical engineering (or an equivalent amount of industry experience) [and] familiarity with pedal control systems for vehicles.'" 298 F. Supp. 2d, at 590. The court then set forth the relevant prior art, in-

cluding the patents and pedal designs described above.

Following *Graham*'s direction, the court compared the teachings of the prior art to the claims of Engelgau. It found "little difference." 298 F. Supp. 2d, at 590. Asano taught everything contained in claim 4 except the use of a sensor to detect the pedal's position and transmit it to the computer controlling the throttle. That additional aspect was revealed in sources such as the '068 patent and the sensors used by Chevrolet.

Under the controlling cases from the Court of Appeals for the Federal Circuit, however, the District Court was not permitted to stop there. The court was required also to apply the TSM test. The District Court held KSR had satisfied the test. It reasoned (1) the state of the industry would lead inevitably to combinations of electronic sensors and adjustable pedals, (2) Rixon provided the basis for these developments, and (3) Smith taught a solution to the wire chafing problems in Rixon, namely locating the sensor on the fixed structure of the pedal. This could lead to the combination of Asano, or a pedal like it, with a pedal position sensor.

The conclusion that the Engelgau design was obvious was supported, in the District Court's view, by the PTO's rejection of the broader version of claim 4. Had Engelgau included Asano in his patent application, it reasoned, the PTO would have found claim 4 to be an obvious combination of Asano and Smith, as it had found the broader version an obvious combination of Redding and Smith. As a final matter, the District Court held that the secondary factor of Teleflex's commercial success with pedals based on Engelgau's design did not alter its conclusion. The District Court granted summary judgment for KSR.

With principal reliance on the TSM test, the Court of Appeals reversed. It ruled the District Court had not been strict enough in applying the test, having failed to make "'finding[s] as to the specific understanding or principle

within the knowledge of a skilled artisan that would have motivated one with no knowledge of [the] invention' . . . to attach an electronic control to the support bracket of the Asano assembly." 119 Fed. Appx., at 288 (brackets in original) (quoting *In re Kotzab*, 217 F. 3d 1365, 1371 (CA Fed. 2000)). The Court of Appeals held that the District Court was incorrect that the nature of the problem to be solved satisfied this requirement because unless the "prior art references address[ed] the precise problem that the patentee was trying to solve," the problem would not motivate an inventor to look at those references. 119 Fed. Appx., at 288.

Here, the Court of Appeals found, the Asano pedal was designed to solve the "'constant ratio problem'"—that is, to ensure that the force required to depress the pedal is the same no matter how the pedal is adjusted—whereas Engelgau sought to provide a simpler, smaller, cheaper adjustable electronic pedal. *Ibid.* As for Rixon, the court explained, that pedal suffered from the problem of wire chafing but was not designed to solve it. In the court's view Rixon did not teach anything helpful to Engelgau's purpose. Smith, in turn, did not relate to adjustable pedals and did not "necessarily go to the issue of motivation to attach the electronic control on the support bracket of the pedal assembly." *Ibid.* When the patents were interpreted in this way, the Court of Appeals held, they would not have led a person of ordinary skill to put a sensor on the sort of pedal described in Asano.

That it might have been obvious to try the combination of Asano and a sensor was likewise irrelevant, in the court's view, because "'"[o]bvious to try" has long been held not to constitute obviousness.'" *Id.*, at 289 (quoting *In re Deuel*, 51 F. 3d 1552, 1559 (CA Fed. 1995)).

The Court of Appeals also faulted the District Court's consideration of the PTO's rejection of the broader version of claim 4. The District Court's role, the Court of Appeals

explained, was not to speculate regarding what the PTO might have done had the Engelgau patent mentioned Asano. Rather, the court held, the District Court was obliged first to presume that the issued patent was valid and then to render its own independent judgment of obviousness based on a review of the prior art. The fact that the PTO had rejected the broader version of claim 4, the Court of Appeals said, had no place in that analysis.

The Court of Appeals further held that genuine issues of material fact precluded summary judgment. Teleflex had proffered statements from one expert that claim 4 "'was a simple, elegant, and novel combination of features,'" 119 Fed. Appx., at 290, compared to Rixon, and from another expert that claim 4 was nonobvious because, unlike in Rixon, the sensor was mounted on the support bracket rather than the pedal itself. This evidence, the court concluded, sufficed to require a trial.

II

A

We begin by rejecting the rigid approach of the Court of Appeals. Throughout this Court's engagement with the question of obviousness, our cases have set forth an expansive and flexible approach inconsistent with the way the Court of Appeals applied its TSM test here. To be sure, *Graham* recognized the need for "uniformity and definiteness." 383 U. S., at 18. Yet the principles laid down in *Graham* reaffirmed the "functional approach" of *Hotchkiss*, 11 How. 248. See 383 U. S., at 12. To this end, *Graham* set forth a broad inquiry and invited courts, where appropriate, to look at any secondary considerations that would prove instructive. *Id.*, at 17.

Neither the enactment of §103 nor the analysis in *Graham* disturbed this Court's earlier instructions concerning the need for caution in granting a patent based on the combination of elements found in the prior art. For over a

half century, the Court has held that a "patent for a combination which only unites old elements with no change in their respective functions . . . obviously withdraws what is already known into the field of its monopoly and diminishes the resources available to skillful men." *Great Atlantic & Pacific Tea Co.* v. *Supermarket Equipment Corp.*, 340 U. S. 147, 152 (1950). This is a principal reason for declining to allow patents for what is obvious. The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. Three cases decided after *Graham* illustrate the application of this doctrine.

In *United States* v. *Adams*, 383 U. S. 39, 40 (1966), a companion case to *Graham*, the Court considered the obviousness of a "wet battery" that varied from prior designs in two ways: It contained water, rather than the acids conventionally employed in storage batteries; and its electrodes were magnesium and cuprous chloride, rather than zinc and silver chloride. The Court recognized that when a patent claims a structure already known in the prior art that is altered by the mere substitution of one element for another known in the field, the combination must do more than yield a predictable result. 383 U. S., at 50–51. It nevertheless rejected the Government's claim that Adams's battery was obvious. The Court relied upon the corollary principle that when the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be nonobvious. *Id.*, at 51–52. When Adams designed his battery, the prior art warned that risks were involved in using the types of electrodes he employed. The fact that the elements worked together in an unexpected and fruitful manner supported the conclusion that Adams's design was not obvious to those skilled in the art.

In *Anderson's-Black Rock, Inc.* v. *Pavement Salvage Co.*, 396 U. S. 57 (1969), the Court elaborated on this approach.

The subject matter of the patent before the Court was a device combining two pre-existing elements: a radiant-heat burner and a paving machine. The device, the Court concluded, did not create some new synergy: The radiant-heat burner functioned just as a burner was expected to function; and the paving machine did the same. The two in combination did no more than they would in separate, sequential operation. *Id.*, at 60–62. In those circumstances, "while the combination of old elements performed a useful function, it added nothing to the nature and quality of the radiant-heat burner already patented," and the patent failed under §103. *Id.*, at 62 (footnote omitted).

Finally, in *Sakraida* v. *AG Pro, Inc.*, 425 U. S. 273 (1976), the Court derived from the precedents the conclusion that when a patent "simply arranges old elements with each performing the same function it had been known to perform" and yields no more than one would expect from such an arrangement, the combination is obvious. *Id.*, at 282.

The principles underlying these cases are instructive when the question is whether a patent claiming the combination of elements of prior art is obvious. When a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a person of ordinary skill can implement a predictable variation, §103 likely bars its patentability. For the same reason, if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill. *Sakraida* and *Anderson's-Black Rock* are illustrative—a court must ask whether the improvement is more than the predictable use of prior art elements according to their established functions.

Following these principles may be more difficult in other

cases than it is here because the claimed subject matter may involve more than the simple substitution of one known element for another or the mere application of a known technique to a piece of prior art ready for the improvement. Often, it will be necessary for a court to look to interrelated teachings of multiple patents; the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art, all in order to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue. To facilitate review, this analysis should be made explicit. See *In re Kahn*, 441 F. 3d 977, 988 (CA Fed. 2006) ("[R]ejections on obviousness grounds cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness"). As our precedents make clear, however, the analysis need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.

B

When it first established the requirement of demonstrating a teaching, suggestion, or motivation to combine known elements in order to show that the combination is obvious, the Court of Customs and Patent Appeals captured a helpful insight. See *Application of Bergel*, 292 F. 2d 955, 956–957 (1961). As is clear from cases such as *Adams*, a patent composed of several elements is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art. Although common sense directs one to look with care at a patent application that claims as innovation the combination of two known devices according to their established

functions, it can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does. This is so because inventions in most, if not all, instances rely upon building blocks long since uncovered, and claimed discoveries almost of necessity will be combinations of what, in some sense, is already known.

Helpful insights, however, need not become rigid and mandatory formulas; and when it is so applied, the TSM test is incompatible with our precedents. The obviousness analysis cannot be confined by a formalistic conception of the words teaching, suggestion, and motivation, or by overemphasis on the importance of published articles and the explicit content of issued patents. The diversity of inventive pursuits and of modern technology counsels against limiting the analysis in this way. In many fields it may be that there is little discussion of obvious techniques or combinations, and it often may be the case that market demand, rather than scientific literature, will drive design trends. Granting patent protection to advances that would occur in the ordinary course without real innovation retards progress and may, in the case of patents combining previously known elements, deprive prior inventions of their value or utility.

In the years since the Court of Customs and Patent Appeals set forth the essence of the TSM test, the Court of Appeals no doubt has applied the test in accord with these principles in many cases. There is no necessary inconsistency between the idea underlying the TSM test and the *Graham* analysis. But when a court transforms the general principle into a rigid rule that limits the obviousness inquiry, as the Court of Appeals did here, it errs.

C

The flaws in the analysis of the Court of Appeals relate

for the most part to the court's narrow conception of the obviousness inquiry reflected in its application of the TSM test. In determining whether the subject matter of a patent claim is obvious, neither the particular motivation nor the avowed purpose of the patentee controls. What matters is the objective reach of the claim. If the claim extends to what is obvious, it is invalid under §103. One of the ways in which a patent's subject matter can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims.

The first error of the Court of Appeals in this case was to foreclose this reasoning by holding that courts and patent examiners should look only to the problem the patentee was trying to solve. 119 Fed. Appx., at 288. The Court of Appeals failed to recognize that the problem motivating the patentee may be only one of many addressed by the patent's subject matter. The question is not whether the combination was obvious to the patentee but whether the combination was obvious to a person with ordinary skill in the art. Under the correct analysis, any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

The second error of the Court of Appeals lay in its assumption that a person of ordinary skill attempting to solve a problem will be led only to those elements of prior art designed to solve the same problem. *Ibid.* The primary purpose of Asano was solving the constant ratio problem; so, the court concluded, an inventor considering how to put a sensor on an adjustable pedal would have no reason to consider putting it on the Asano pedal. *Ibid.* Common sense teaches, however, that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a

puzzle. Regardless of Asano's primary purpose, the design provided an obvious example of an adjustable pedal with a fixed pivot point; and the prior art was replete with patents indicating that a fixed pivot point was an ideal mount for a sensor. The idea that a designer hoping to make an adjustable electronic pedal would ignore Asano because Asano was designed to solve the constant ratio problem makes little sense. A person of ordinary skill is also a person of ordinary creativity, not an automaton.

The same constricted analysis led the Court of Appeals to conclude, in error, that a patent claim cannot be proved obvious merely by showing that the combination of elements was "obvious to try." *Id.*, at 289 (internal quotation marks omitted). When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try might show that it was obvious under §103.

The Court of Appeals, finally, drew the wrong conclusion from the risk of courts and patent examiners falling prey to hindsight bias. A factfinder should be aware, of course, of the distortion caused by hindsight bias and must be cautious of arguments reliant upon *ex post* reasoning. See *Graham*, 383 U. S., at 36 (warning against a "temptation to read into the prior art the teachings of the invention in issue" and instructing courts to "'guard against slipping into the use of hindsight'" (quoting *Monroe Auto Equipment Co.* v. *Heckethorn Mfg. & Supply Co.*, 332 F. 2d 406, 412 (CA6 1964))). Rigid preventative rules that deny factfinders recourse to common sense, however, are neither necessary under our case law nor consistent with it.

We note the Court of Appeals has since elaborated a

broader conception of the TSM test than was applied in the instant matter. See, *e.g., DyStar Textilfarben GmbH & Co. Deutschland KG* v. *C. H. Patrick Co.*, 464 F. 3d 1356, 1367 (2006) ("Our suggestion test is in actuality quite flexible and not only permits, but *requires*, consideration of common knowledge and common sense"); *Alza Corp.* v. *Mylan Labs., Inc.*, 464 F. 3d 1286, 1291 (2006) ("There is flexibility in our obviousness jurisprudence because a motivation may be found *implicitly* in the prior art. We do not have a rigid test that requires an actual teaching to combine . . ."). Those decisions, of course, are not now before us and do not correct the errors of law made by the Court of Appeals in this case. The extent to which they may describe an analysis more consistent with our earlier precedents and our decision here is a matter for the Court of Appeals to consider in its future cases. What we hold is that the fundamental misunderstandings identified above led the Court of Appeals in this case to apply a test inconsistent with our patent law decisions.

III

When we apply the standards we have explained to the instant facts, claim 4 must be found obvious. We agree with and adopt the District Court's recitation of the relevant prior art and its determination of the level of ordinary skill in the field. As did the District Court, we see little difference between the teachings of Asano and Smith and the adjustable electronic pedal disclosed in claim 4 of the Engelgau patent. A person having ordinary skill in the art could have combined Asano with a pedal position sensor in a fashion encompassed by claim 4, and would have seen the benefits of doing so.

A

Teleflex argues in passing that the Asano pedal cannot be combined with a sensor in the manner described by

claim 4 because of the design of Asano's pivot mechanisms. See Brief for Respondents 48–49, and n. 17. Therefore, Teleflex reasons, even if adding a sensor to Asano was obvious, that does not establish that claim 4 encompasses obvious subject matter. This argument was not, however, raised before the District Court. There Teleflex was content to assert only that the problem motivating the invention claimed by the Engelgau patent would not lead to the solution of combining of Asano with a sensor. See Teleflex's Response to KSR's Motion for Summary Judgment of Invalidity in No. 02–74586 (ED Mich.), pp. 18–20, App. 144a–146a. It is also unclear whether the current argument was raised before the Court of Appeals, where Teleflex advanced the nonspecific, conclusory contention that combining Asano with a sensor would not satisfy the limitations of claim 4. See Brief for Plaintiffs-Appellants in No. 04–1152 (CA Fed.), pp. 42–44. Teleflex's own expert declarations, moreover, do not support the point Teleflex now raises. See Declaration of Clark J. Radcliffe, Ph.D., Supplemental App. 204–207; Declaration of Timothy L. Andresen, *id.*, at 208–210. The only statement in either declaration that might bear on the argument is found in the Radcliffe declaration:

> "Asano . . . and Rixon . . . are complex mechanical linkage-based devices that are expensive to produce and assemble and difficult to package. It is exactly these difficulties with prior art designs that [Engelgau] resolves. The use of an adjustable pedal with a single pivot reflecting pedal position combined with an electronic control mounted between the support and the adjustment assembly at that pivot was a simple, elegant, and novel combination of features in the Engelgau '565 patent." *Id.*, at 206, ¶16.

Read in the context of the declaration as a whole this is best interpreted to mean that Asano could not be used to

solve "[t]he problem addressed by Engelgau '565[:] to provide a less expensive, more quickly assembled, and smaller package adjustable pedal assembly with electronic control." *Id.*, at 205, ¶10.

The District Court found that combining Asano with a pivot-mounted pedal position sensor fell within the scope of claim 4. 298 F. Supp. 2d, at 592–593. Given the sigificance of that finding to the District Court's judgment, it is apparent that Teleflex would have made clearer challenges to it if it intended to preserve this claim. In light of Teleflex's failure to raise the argument in a clear fashion, and the silence of the Court of Appeals on the issue, we take the District Court's conclusion on the point to be correct.

B

The District Court was correct to conclude that, as of the time Engelgau designed the subject matter in claim 4, it was obvious to a person of ordinary skill to combine Asano with a pivot-mounted pedal position sensor. There then existed a marketplace that created a strong incentive to convert mechanical pedals to electronic pedals, and the prior art taught a number of methods for achieving this advance. The Court of Appeals considered the issue too narrowly by, in effect, asking whether a pedal designer writing on a blank slate would have chosen both Asano and a modular sensor similar to the ones used in the Chevrolet truckline and disclosed in the '068 patent. The District Court employed this narrow inquiry as well, though it reached the correct result nevertheless. The proper question to have asked was whether a pedal designer of ordinary skill, facing the wide range of needs created by developments in the field of endeavor, would have seen a benefit to upgrading Asano with a sensor.

In automotive design, as in many other fields, the interaction of multiple components means that changing one

component often requires the others to be modified as well. Technological developments made it clear that engines using computer-controlled throttles would become standard. As a result, designers might have decided to design new pedals from scratch; but they also would have had reason to make pre-existing pedals work with the new engines. Indeed, upgrading its own pre-existing model led KSR to design the pedal now accused of infringing the Engelgau patent.

For a designer starting with Asano, the question was where to attach the sensor. The consequent legal question, then, is whether a pedal designer of ordinary skill starting with Asano would have found it obvious to put the sensor on a fixed pivot point. The prior art discussed above leads us to the conclusion that attaching the sensor where both KSR and Engelgau put it would have been obvious to a person of ordinary skill.

The '936 patent taught the utility of putting the sensor on the pedal device, not in the engine. Smith, in turn, explained to put the sensor not on the pedal's footpad but instead on its support structure. And from the known wire-chafing problems of Rixon, and Smith's teaching that "the pedal assemblies must not precipitate any motion in the connecting wires," Smith, col. 1, lines 35–37, Supplemental App. 274, the designer would know to place the sensor on a nonmoving part of the pedal structure. The most obvious nonmoving point on the structure from which a sensor can easily detect the pedal's position is a pivot point. The designer, accordingly, would follow Smith in mounting the sensor on a pivot, thereby designing an adjustable electronic pedal covered by claim 4.

Just as it was possible to begin with the objective to upgrade Asano to work with a computer-controlled throttle, so too was it possible to take an adjustable electronic pedal like Rixon and seek an improvement that would avoid the wire-chafing problem. Following similar steps to

those just explained, a designer would learn from Smith to avoid sensor movement and would come, thereby, to Asano because Asano disclosed an adjustable pedal with a fixed pivot.

Teleflex indirectly argues that the prior art taught away from attaching a sensor to Asano because Asano in its view is bulky, complex, and expensive. The only evidence Teleflex marshals in support of this argument, however, is the Radcliffe declaration, which merely indicates that Asano would not have solved Engelgau's goal of making a small, simple, and inexpensive pedal. What the declaration does not indicate is that Asano was somehow so flawed that there was no reason to upgrade it, or pedals like it, to be compatible with modern engines. Indeed, Teleflex's own declarations refute this conclusion. Dr. Radcliffe states that Rixon suffered from the same bulk and complexity as did Asano. See *id.*, at 206. Teleflex's other expert, however, explained that Rixon was itself designed by adding a sensor to a pre-existing mechanical pedal. See *id.*, at 209. If Rixon's base pedal was not too flawed to upgrade, then Dr. Radcliffe's declaration does not show Asano was either. Teleflex may have made a plausible argument that Asano is inefficient as compared to Engelgau's preferred embodiment, but to judge Asano against Engelgau would be to engage in the very hindsight bias Teleflex rightly urges must be avoided. Accordingly, Teleflex has not shown anything in the prior art that taught away from the use of Asano.

Like the District Court, finally, we conclude Teleflex has shown no secondary factors to dislodge the determination that claim 4 is obvious. Proper application of *Graham* and our other precedents to these facts therefore leads to the conclusion that claim 4 encompassed obvious subject matter. As a result, the claim fails to meet the requirement of §103.

We need not reach the question whether the failure to

disclose Asano during the prosecution of Engelgau voids the presumption of validity given to issued patents, for claim 4 is obvious despite the presumption. We nevertheless think it appropriate to note that the rationale underlying the presumption—that the PTO, in its expertise, has approved the claim—seems much diminished here.

IV

A separate ground the Court of Appeals gave for reversing the order for summary judgment was the existence of a dispute over an issue of material fact. We disagree with the Court of Appeals on this point as well. To the extent the court understood the *Graham* approach to exclude the possibility of summary judgment when an expert provides a conclusory affidavit addressing the question of obviousness, it misunderstood the role expert testimony plays in the analysis. In considering summary judgment on that question the district court can and should take into account expert testimony, which may resolve or keep open certain questions of fact. That is not the end of the issue, however. The ultimate judgment of obviousness is a legal determination. *Graham*, 383 U. S., at 17. Where, as here, the content of the prior art, the scope of the patent claim, and the level of ordinary skill in the art are not in material dispute, and the obviousness of the claim is apparent in light of these factors, summary judgment is appropriate. Nothing in the declarations proffered by Teleflex prevented the District Court from reaching the careful conclusions underlying its order for summary judgment in this case.

* * *

We build and create by bringing to the tangible and palpable reality around us new works based on instinct, simple logic, ordinary inferences, extraordinary ideas, and sometimes even genius. These advances, once part of our

shared knowledge, define a new threshold from which innovation starts once more. And as progress beginning from higher levels of achievement is expected in the normal course, the results of ordinary innovation are not the subject of exclusive rights under the patent laws. Were it otherwise patents might stifle, rather than promote, the progress of useful arts. See U. S. Const., Art. I, §8, cl. 8. These premises led to the bar on patents claiming obvious subject matter established in *Hotchkiss* and codified in §103. Application of the bar must not be confined within a test or formulation too constrained to serve its purpose.

KSR provided convincing evidence that mounting a modular sensor on a fixed pivot point of the Asano pedal was a design step well within the grasp of a person of ordinary skill in the relevant art. Its arguments, and the record, demonstrate that claim 4 of the Engelgau patent is obvious. In rejecting the District Court's rulings, the Court of Appeals analyzed the issue in a narrow, rigid manner inconsistent with §103 and our precedents. The judgment of the Court of Appeals is reversed, and the case remanded for further proceedings consistent with this opinion.

It is so ordered.

EXHIBIT K

THIS EXHIBIT HAS BEEN REDACTED IN ITS ENTIRETY